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THE MISSION OF SCIENCE:

AN ORATION DELIVERED AT THE PHILADELPHIA MEETING (SEPT., 1884) OF THE AMERICAN ASSOCIATION FOR ADVANCEMENT OF SCIENCE.

By Vice-President ROBERT H. THURSTON, Chairman of Section D (Mechanics).

Before taking up the subject which I have selected as a proper one for discussion in a vice-president's address, on this occasion, I desire to give expression to my sense of the great honor which has been conferred upon me in calling me, for a third time, to the chair of vice-president of the American Association for Advancement of Science, and to preside at the sessions of the section. In taking the position to which your too favorable judgment has called me, it is my first and most pleasant duty to thank you for this most unequivocal testimony of the confidence which you repose in me, and to assure you of my earnest desire to do what little my opportunities and my powers may permit toward making your sessions both pleasant and profitable, and toward promoting the prosperity of the great association to which we are proud to belong.

We are especially favored, the present year, in having with us members of our great sister society, the British Association for Advancement of Science, who have come to join us from Montreal, where the meeting of that society has just been held, and where they have taken part in proceedings of no less importance than interest. It is our pleasant duty to tender to these gentlemen a hearty welcome, and to endeavor to make their visit to the "City of Brotherly Love" one that shall leave in their memories so many reminiscences of agreeable acquaintances made, of strong friendships begun, of open handed and open hearted hospitalities, and of profitable and interesting discussions, that they may never forget the cognomen of this noble city. If we shall be able to give them but a suggestion of the pleasure and the profit gained by those of our own number who were so fortunate as to be able to accept their generous and whole-souled greetings at Montreal, we may well be content. We can at least do our best to convince them that the capital of the "Keystone State," the first capital of the United States, is at least as well entitled to the fraternal regard of our British guests as is the beautiful Canadian city from which they are just come.

As time goes on with steady and unvarying sweep toward the eternity of the future, and as our two nations, our one, hardly divided, people, are becoming bound more and more closely by every interest, and by all memories of the past, by all the sympathies that are engendered in the breasts of members of one race and of one great family; and as we are more and more closely tied by the bonds typified by the continually increasing number of the great cables of steel

nerves that stretch across the ocean which now only nominally separates us, and as we find the once seemingly infinite expanse of that ocean narrowed by that most wonderful of the products of the growth of the science and the art of mechanics, the modern steamship, until the weeks of the past have become the days of the present; as we are beginning to realize the fact of the true unity of the human race, and the duty that lies with us to promote, in every one of the thousand ways that men of science, more than all other men, can effectually work, that spirit of self-abnegation and philanthropy, regulated by the principle of intelligent and honorable self-protection, upon which we are beginning to see that we must, and ought to, rely for the amelioration of the countless evils which are to-day a consequence of selfish and unintelligent human actions, this bond becomes strengthened in numberless ways. We fully realize that "in union is strength," and that the fraternal sentiment which we hope that these meetings are effectively promoting may be a very important factor in the solution of a problem—that of the reduction of the sum of evil in the world—which has been earnestly studied by every thinker since the world began. In behalf of the members of this body, I extend the right hand of fellowship to our guests, and bid them heartily welcome to all that we may be able to offer, and to share with them, at this meeting.

Gentlemen of the section and friends who have honored us with your cheering presence. It is just two hundred years since, in deference to the enlightened views of Sir John Cutler, the Chair of Mechanics was founded in the Royal Society of Great Britain. May we not hope that this Section of Mechanics of the American Association for Advancement of Science may prove to be worthy, in its interest, its fruitfulness, and its stimulation of other and greater work, of so grand an anniversary?

THE MISSION OF SCIENCE.

I have selected the subject of my address on this occasion, "The Mission of Science," as one peculiarly appropriate to the time and the occasion.

Seven years ago, at the Nashville meeting, I was called, by the members of what was then Section A of this association, to take the chair, in the absence of the regularly elected vice-president for that meeting, and performed the pleasant task of reading an address, prepared by him, on the "Endowment of Science." Before the meeting of 1878, at St. Louis, in the regular course of my duties as vice-president, and as chairman of the same section, it became necessary to prepare an address to be delivered before the association, and the subject then chosen was "The Philosophic method of Advancement of Science," or, perhaps more explicitly, The Science of the Advancement of Science. In the first of these addresses, the attention of the association was earnestly called to the necessity of increasing the efficiency of scientific work, and of making most fruitful the labor of the comparatively few workers in this field, in the United States, by securing such an endowment of research as is now, fortunately for our nation, becoming usual in the departments of higher education. In the second of these discourses, I endeavored to point out what, in my opinion, is the truly scientific method of securing the greatest possible results with minimum expenditure of life, strength, mind and matter, and at least cost to the world.

I defined science, substantially, as knowledge systematically organized. I then called attention to the facts that it consists of two divisions: knowledge of phenomena gathered by observation and experiment, and knowledge of laws controlling and correlating these phenomena. As then stated, "all science is thus made up from the infinite number of facts which are comprehended in the universe of the known and the to be-known. Its existence is assured by the stability of all those principles of philosophy which are woven into the connecting chain." "The man of science, the philosopher whose task it is to create and to advance all human knowledge of the great kingdom of nature, is, therefore, a discoverer of facts, an observer of phenomena, a student of Nature's laws. He is a systematic recorder of facts, and a codifier of laws." It was shown that all science has for its foundation the great, the fundamental principle of the indestructibility of "the two products of creation, matter and force, and the fruit

of their union, energy." The next step in the argument led to the classification of the forces of nature into physical—including chemical—vital, mental, and "the master-power, Omnipotence, which is the source and the sustainer of all existences," and this division leads naturally to a similar division of science into physical, biological and mental sciences. It is with the first of these grand divisions of science, only, that we are concerned.

The scientific method of advancing science was shown to comprehend a systematic collection of all facts and phenomena, as exhibited to the senses in the course of our experience, either by simple observation or by carefully conducted experiment; the systematic arrangement of the knowledge so obtained, and the registration of this knowledge in natural order and relations: the study of such recorded facts of science with the purpose of ascertaining the laws that define their relations; the similar co-ordination of separate collections of such related facts and laws, for the purpose of detecting the character and the mathematical form of the more general laws that may determine the relations of group to group and of science to science; and, finally, the aggregation, if it prove to be possible, of all science into one universal system comprehending all the phenomena of nature.

To accomplish this great work there are needed several classes of workers, each of whom, to secure maximum efficiency, must be a specialist, and must give his time and his thought and his strength mainly to a single line of work. We must have observers, each of whom should be fitted by every natural endowment for the study of nature, and for the investigation, by direct experiments intelligently planned and skillfully conducted, of the natural phenomena which are characteristic of, and, perhaps, peculiar to, his branch. We must have philosophers capable of perceiving and expressing the relations of the phenomena so collected, and of thus revealing to us the laws of each of the sciences. We need men who can perceive and exhibit the relations of the several sciences to each other, and their positions in the scheme of universal science. Finally, we require a still larger and more directly useful class, the teachers of science and the no less important body of laborers who make application of science in all the arts of daily life and work.

But all of these classes being organized, and all the fields of work open to man being assigned to them, each taking his proper division of the great task, progress would be but slow, and, in these days almost at a standstill, but for the aid of still another body of co-laborers, who, without pretending to deep knowledge in any division of science, without possessing talent for research, either in the laboratory or in the study, and unable often to realize all the beauty and all the importance of the mighty work that they are helping on, nevertheless generously devote the fruit of years of toil and the product of enormous activities and energy to the cause. These are those who have given, and who are still generously and liberally giving, material assistance by their splendid contributions to the scientific departments in our colleges and of our technical schools. The endowment of research, which will certainly ere long become an acknowledged and legitimate division of this work, is, after all, as essential an element of the scientific method of advancing science as either of the others. Those who give of their substance to aid in the promotion of science are entitled to hardly less honor than those who devote life and health and strength to the good work. Those who take part in the endowment of research are the truest and greatest of modern philanthropists.

When we have thus ascertained what is the philosophic method of the advancement of science, and have determined how we may most efficiently carry on the work in the true spirit of the "science of science-advancement," we may find it to our advantage to pause, and to ask to what end is all this labor to be applied. What is the object of directing this enormous array of intellectual power into the field of scientific inquiry? Having settled upon the form of the system, and the details of the mechanism by which this development of science is to be secured with greatest ease, accuracy and rapidity, to what purpose is this great scheme to be applied? What is the use, and what is the object, of systematically gathering knowledge and of constructing

a great, an elaborate, system having the promotion of science as its sole end and aim? What is "THE MISSION OF SCIENCE?"

The mission of science is the promotion of the welfare, material and spiritual, physical and intellectual, of the human race. It has for its purpose and its object the improvement, in every imaginable way, directly and indirectly, of the mind and the body, the heart and the soul, of every human being. It is charged with the duty of seeking the cause of every ill to which mankind is subject; of finding a remedy for every misfortune to which the race is now liable; of ameliorating every misery known to sage or savage; of seeking ways of giving to all every comfort and all healthful luxuries; of reducing the hours of toil, and offering to the relieved laborer intellectual occupations that shall at once take from him all temptation to waste his life in indolence and dissipation and give him aid in his feeble efforts to climb upward into a higher life; of enlightening the world intellectually; of giving it leisure to perfect itself ethically, and to gain those elements of character that are so sadly crushed out by the terrible pressure of our incomplete civilization, sentiments of honor and justice, feelings of love and sympathy, and a spirit of devotion that can only be found highly developed in either the simple child of nature, or in the soul that has time, in the midst of a driving world, to reflect, to aspire and to grow. The true mission of science is one that extends far beyond the workshop of its servants; it extends far beyond our ken, and beyond the range of our mental grasp and farthest view. The great fact that material prosperity is the fruit of science, and that other great truth, that as mankind is given opportunity for meditation and for culture, the higher attributes of human character are given development, are the best indications of the nature of the real mission of science, and of the correctness of the conclusion that the use and the aim of scientific inquiry are to be sought in the region beyond and above the material world to which those studies are confined.

The Mission of Science will be fulfilled in precisely the degree to which it assists us in the protection and preservation of the individual, of the family and of the nation; just so far as it aids each member of the race to attain the alloted term of life, continuous health, and a maximum of happiness, while, at the same time, giving him the opportunity to assist his neighbor most effectively in the endeavor to reach the same ends, and so far as it stimulates him to do well every duty that comes to him whether in his private or his public relations. It will aid every citizen in his efforts to gain the most that can be secured by the practice of industry, skill, intelligence and frugality, to obtain the comfortable independence that every man hopes to enjoy in his old age, and the means of carrying his children on to a higher plane than that upon which he himself entered when taking up his life's work.

The methods properly adopted in the endeavor to prosecute this mission, so far as they relate to the development of the sciences, have been already summarized. It has been seen that the method is in itself scientific. Science first observes, then experiments with a view to the revelation of new facts and unknown laws by systematic research, then applies the power of logic to the construction of an organized, complete and exact system of definite knowledge. First she collects facts and records phenomena, then she seeks to discover and exactly to enunciate the laws controlling them, and finally produces, by the intelligent use both of induction and deduction, a symmetrical and perfect whole. Thus she creates systems of knowledge, and thus she will sometime, we may hope, knit these several systems into one great all-embracing system of the universe.

But, while this scientific method of advancement of science is evidently that which will yield the greatest returns, it is not the fact that we are indebted to such philosophic methods for the production of the modern sciences. It is a fact which is more significant than surprising that, as Whewell remarks, "art has always gone in advance and science has followed to give the reasons for the phenomena discovered and the methods found best in art." "Art is the parent, not the progeny, of science," and, while it is true that progress is always most rapid and most satisfactory when art and science go hand in hand, it has been al-

most invariably the case that art has struggled painfully and haltingly, and doubtfully onward, in every department, slowly and unsteadily advancing, yet almost always going before science, who should have been her leader, her teacher, and her most powerful supporter. This fact is not to be considered as representing a natural state of things nor as in the slightest degree discouraging. Like every art, science, in each of its departments, has been passing through a period of infancy, during which it knew neither its powers, its object or mission, nor its proper methods of work. It required protection and the aid of art until it should be fully formed and competent to take up its labors and to requite the assistance which had been given it. In the past the arts have led; in the future we shall see science leading and directing every development of the arts. History tells us that bleaching and dyeing were familiar arts before the science of chemistry had a name; the inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of; the telegraph and the telephone, the electric light and the railroad, have made us familiar with marvels greater than those of fiction, and yet have been principally developed, in every instance, by men who had acquired less of scientific knowledge than we demand to-day of every college-bred lad.

But all this is of the past. Science has attained a development, a stature and a power, that gives her the ability to assume her place in the great scheme of civilization. Hereafter she will direct and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end, methods now daily practised by the engineer in designing his machinery. Instead of long, discouraging, and painful, efforts to reach a result which is indistinctly defined, science will, hereafter, first determine just what is the end to be sought, and then will show the direct line to that end. Uncertainty will give place to certainty, and wasted work will be reduced to the least possible amount.

The aids to science have been already briefly referred to. They are partly material, partly moral, partly intellectual. In the very infancy of civilization the most efficient aids were tendered freely to science. The rulers of the earliest historic nations gave encouragement to the sciences, such as they were in their day; governments founded universities in the days of the Greeks and the Romans; the greatest minds of those times were led to turn their attention to philosophy, and students in thousands thronged the schools. Aristotle made a rude yet definite beginning in the physical sciences; Alexander endowed research most liberally in the person of his great master; the same great warrior urged upon Nearchus the prosecution of the greatest of his plans of geographical exploration, and gave him means to carry out his schemes; an enormous library at Alexandria furnished the student the then available knowledge of the world; the enormous "museum" in which it was preserved gave an impetus to science that has never been lost; Euclid, Archimedes, Eratosthenes, Hipparchus and Hero, those wonderful men who gave us geometry, taught us the elements of mechanics, the principles of hydrostatics and the lever, founded systematic astronomy and physical geography, put on record the earliest notions of the correct form of the earth and the motions of the moon, catalogued the stars, and measured their angular distances, and who first used and described the germ of the steam engine and a thousand other mechanical inventions, were themselves the product of an enlightened policy.

The Arabians transferred the seat of science to the west, and erected her capital at the shore of the Atlantic. Experimental science there had a new birth, and the wealth of the Saracens, and the intellect of the greatest among the Moors and the Jews, there contributed to the growth of real knowledge. Alchemy, the parent of chemistry, was there born, and her progress has never since been interrupted. Marcus Graecus' gunpowder, the more powerful acids, phosphorus, and systematic chemical methods of investigation, are some of the products of the intellectual activity of that time.

Centuries later, and after a period of stagnation and darkness, the light again flashes up and this time it appears in what is now the home of European civilization. The extension of commerce leads to maritime discovery; the awakening of the people by these, to them, startling discoveries, leads to progress in every direction. Galileo and Bruno die that science may forever live; the invention of the telescope stimulates astronomical discovery, and the formation of the modern science of the solar and sidereal systems; the magnificent labors of Newton illustrate the progress of the sciences of physics and mechanics. Every branch of natural philosophy grows and puts forth branches in turn, and the idea of the universal dominion of physical laws becomes accepted as a foundation principle in science, and as the basis of the operations of the universe. Geology, ethnology, physiology, the broader science of biology, take form and grow with astonishing rapidity; and, with their growth, come the minor sciences and the enormous mass of underlying facts determined by the now well-established methods of scientific investigation. Finally, in the later times, in which the last three or four generations have borne a part, science and art have learned to work together, and have gone on, hand in hand, each aiding the other, art supplying facts, science finding out nature's laws as illustrated in those facts, and both, gradually, and more and more rapidly and fully, revealing the beautiful and wonderful system upon which the world is constructed, and all its curious operations carried on, while, at the same time, applying useful knowledge, thus acquired, in promoting the welfare of the human race. Electricity and magnetism, light and heat, and every form of physical energy and of active force, have become revealed to man in all their relations, and in all their methods of operation. Discoveries in physics and chemistry succeed each other with a rapidity that taxes even the specialist who endeavors to keep himself informed in regard to them. Mechanical inventions crowd into our life with such wonder-working results that every day sees a new task accomplished that, the day before, would have been regarded as little less than miraculous. The human voice is transmitted a thousand miles, the written word is sent across the bed of an ocean three thousand miles wide, almost in less time than is required to write it; the traveler breakfasts at Boston, dines at New York, and sups at Washington on the same day. Ten thousand tons are transported from continent to continent, over fifty degrees of longitude, in six days; one workman, with the assistance of machinery, produces more than, a century ago, could a hundred men, doing their best, in the earlier rude ways. We read, in the beam of light, the distance and the rate of motion of the stars, and learn in the same wonderful system of ethereal waves, to determine the nature of the matter of which those stars are composed. Man is turning his work in the world over to the more exact and more powerful machines that he has devised and built, and machinery here weaves his cloths, there gathers his grain, and yonder makes for mankind other machines, doing its work with a strength that is never over-taxed, and an endurance that is never found to reach a limit. Relieved from bodily toil, mankind is coming to that condition of social life in which mental activity absorbs its surplus energies, and the material and intellectual development of civilization are carried on together, and with continually accelerated progress.

This is the history of the past, and this is the picture of the growth of science which we are to study to obtain an idea of what shall be its future. Whenever and wherever the mind has been set free to study and to meditate, to observe and to experiment, science has advanced, and the whole race has felt the benefits of her labors.

This work of science has always demanded the material assistance of acquired wealth, and has given to the investment so made its highest return, its best and most bountiful reward. Whenever and wherever, in the future, science shall have the substantial aid that she needs to secure permanent and convenient quarters, and to prosecute her work, then and there will the progress of mankind be accelerated; and this acceleration will be in proportion to the completeness with which the scientific method of promotion of science is adopted. The characteristics of stationary periods, ac-

cording to Whewell, are "obscurity of thought, servility, an intolerant disposition, and an enthusiastic temper." Science teaches exactness and clearness of thought and expression, perfect independence of mind, the most absolute tolerance of honestly held and frankly expressed opinion, and a quiet coolness of action and a deliberation, however enthusiastic may be the nature of the individual, that may be depended upon to yield a correct judgment. The rapidity of recent changes in our methods of work is due very largely to the introduction and extension of these characteristics of the scientific method, and to the influence of the scientific spirit upon mankind.

It is only in modern times, and since the old spirit of contempt for art, and of reverence for the non-utilitarian element in science, has become nearly extinguished, and since our systems of education have begun to include the study of physical science, that we have had what is properly called a division of "Applied Science." In the days of classical learning, science was only valued as it developed a system of purely intellectual gymnastics; the old Socratic spirit still survives, but is fortunately without influence upon our modern life. Socrates rejected and condemned all physical and mathematical science, and, seeking to impart his own contempt for real knowledge to his disciples, urged upon them the study, exclusively, of ethical philosophy, while, at the same time, himself failing to give to his followers a real system of morals. He accused men of science of reaching vain conclusions, while he was himself lost in the labyrinth of his own indefinite and baseless speculations. Plato followed in the same track, developing splendid ideas by uniting the power of a great intellect with the brightness of primitive imagination, and awakening noble sentiments while giving no assistance to his poor fellow-creatures who desired to conquer the necessary leisure for the enjoyment of life. Aristotle in physics, and Zeno in ethics, employed the scientific method, but their achievements were only appreciated in proportion to their inutility. Archimedes was the most perfect prototype, in those days, of the modern physicist and mechanician, of the scientific man and engineer; yet he, and all of his contemporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid or the composition of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever which might "move the world." His enumeration of the sands of the seashore was looked upon as a nobler accomplishment than the invention of the catapult, or of the pump, which, twenty-one centuries after his death, still bears his name.

No system of applied science could exist among people who had no conception of the true mission of science, and it was not until many centuries had passed that mankind reached such a position in their slow progress toward a real civilization, that it became possible to effect that union of science and the arts which is the distinguishing characteristic of the age in which we live. It was not until the middle of the sixteenth century that Copernicus and the modern system of astronomy became possible; Columbus lived but a little earlier; Gilbert, also, a little later, supplied a basis for the science of magnetism; Galileo applied his genius to the production of the telescope. His first use of the new invention was to earn martyrdom by its application to the proof of the truth of the Copernican system, one of the most splendid of all the achievements of applied science. The revelation of the phases of Venus was one of the facts which marks the conversion of the world from the old Greek methods of scientific thought. It was not until the middle of the fifteenth century that Europe could produce a Leonardo da Vinci, the first of the great mechanics and engineers of modern times. Taking up the work of applying science where his predecessor, Archimedes, had left it, seventeen centuries before, he accomplished an amount of work in the application of the physical sciences and of the science of mechanics, that few men in later times have been able to approach, and none, probably, to equal. He revealed the theory of the lever, extending the work of Archimedes to the more general case; he was acquainted with the laws of hydraulics, understood the nature and effects of

friction, and, to a certain extent, its laws. Stevinus followed da Vinci, and Galileo's treatise on mechanics, which appeared in 1592, and his "dialogues" of 1633, crystallized the knowledge of his time in accessible and practically available form. Then came Torricelli, and, a little later, that greatest of English philosophers and mechanicians, Newton, whose "Principia" has been, from 1686 to the present time, a mine which has richly repaid all the less illustrious workers who have chosen to explore it. This wonderful geometer gave all his mighty intellectual power to the work of usefully applying science. He enunciated the laws of motion, deduced the law of gravitation, proved, by the application of his cumbersome but fruitful methods, the exactness of Kepler's laws, showed their generality, and pointed out the fact that they hold the planets in their orbits, and sway the whole stellar world.

The time of Newton marks the beginning of a grand outburst of energy in the useful application of the sciences. Every art, every industry, every phase of human life, felt its helping hand. Inventions began to appear, to relieve the delving laborer, in every department of human industry. The arts began to find a scientific basis, and to look to science for aid in their perfection and in their development; the industries began to feel the stimulating effect of scientific discoveries, and of the introduction of scientific methods of application of practical knowledge; Descartes, Newton and Leibnitz advanced mathematics to a point from which only a Hamilton or a Sylvester could carry it further; Lavoisier and his contemporaries, only a century before our own time, created chemistry; geology had its birth almost within the memory of our elder colleagues; the several departments of physics have taken definite shape almost within our own shorter memories; the natural sciences have come into being since the time of Cuvier and Linnaeus; the greater science of "energetics" is hardly yet defined, and has not taken its place in the text-books taught in even our schools of science. We are, in fact, at the very threshold of the true era of applied science.

In illustration of the gradual evolution and growth of correct theory, and of this slow development of rational views, of the methods of scientific deduction, and of the invariably tardy progress from a beginning distinguished by defective knowledge and inaccurate logic, in the presence of what are later seen to be plainly visible facts, and of what ultimately seem obvious principles, observe the rise and progress of our hardly yet completed theory of that greatest of human inventions—the steam-engine.

Studying the history of the development of this theory, it cannot fail to become strikingly evident that, throughout, experimental knowledge and practical construction have been constantly in advance of the theory, and that the science of the conversion of heat-energy into mechanical power has, in all stages of this progress, come in simply to confirm general conclusions previously reached by deduction from experience and observation, to give the reasons for well-ascertained facts and phenomena, and often—not always promptly or exactly—to define the line of improvement, and the limitations of such advance.

The theory itself began by the correlation of the facts determined by the experiments of Rumford and Davy, at the beginning of the century, those announced by Joule and Thompson many years later, and the laws developed by Clausius, Rankine, and Thompson, at the middle of the century. But Watt had discovered the facts which have since been found to set limits to the efficiency of the engine, a hundred years ago; Smeaton, in many respects, the greatest mechanical engineer of his time, made practically useful application of the knowledge so acquired, and endeavored to secure immunity from these wastes by thoroughly philosophical methods. Clark, a generation ago, showed how the losses first detected by Watt set a definite limit, under the conditions of familiar practice, to the gain to be secured by the expansion of steam; and Cotterill within a few years has shown, by beautiful methods of treatment, their magnitude, and how these wastes take place. Hirn and Leloutre, in France, have similarly thrown light upon the phenomena of "cylinder-condensation," and De Freminville has suggested the method of remedy. Yet it is only now that we are beginning to see that the philosophy of

heat-engines is not simply a thermo-dynamic theory, and that it involves problems in physics, and a study of the methods of conduction and transfer of heat without doing work from point to point in the engine. We are only now learning how to apply to knowledge gained by Isherwood twenty years ago, and by Hirn and by Clark still earlier, in solving the problem of maximum efficiency of the steam-engine. We have only now discovered that the "curve of efficiency," as I have taken the liberty of calling it, is not the curve of mean pressure for "adiabatic" expansion, as Rankine called it, for "isentropic" expansion, as Clausius would call it, but that it is a curve of very different form and location, and that it is variable with every physical condition affecting the working of the expanding fluid in the engine. We have only now learned that every heat-engine has a certain "ratio of expansion for maximum efficiency," which marks the limit to gain in economy by expansion, which limit is fixed for each engine by the nature of the expansion, and the method and extent of wastes of heat. All the facts of this case were apparently as obvious, as easily detected and weighed in their influence upon the theory of heat-engines, years ago, as to-day. Even the latest phase of the current discussion of efficiencies of heat-engines, that relating to their commercial efficiency, would seem to have been as ready for development a generation ago, when first noted by Rankine, as to-day; yet, what is now known as a simple and easily formulated theory has been several decades in growing into shape, notwithstanding that all the needed facts were known, or readily determinable, at the very beginning of the period marked by its evolution. It is only within a year or two that it has become possible to say that the theory of the steam-engine, as a case in applied mechanics, has become so complete that the engineer can safely rest upon it in the preparation of his designs, and in his calculations of power, economy, and commercial efficiency.

Even in the lowest department of applied mechanics, that which forms the basis of the work of the engineer—that including the study of the materials of construction—our knowledge, scientific or general, has been wonderfully slow of development. Experimental work may be said to have commenced in this field a century ago, and the labors of Muschenbroeck, of Tredgold, of Barlow and of Hodgkinson, of Fairbairn, and of their coadjutors of the first half of the century, gave to the constructor and to the theorist the facts which were most essential to their work. But it is only within the past few years that the conditions modifying the value of these materials, as applied in engineering, have been carefully and critically studied by the light of experimental investigation. The effect of heat upon strength and elasticity, the alteration of structure produced by vibration, the difference in carrying power and in safe loading, due to reversed stresses, the modification of the value of steel by alteration of chemical composition and by various modes of tempering, the effect of that singular phenomenon, the variation of the normal line of elastic limits by strain, the persistence of the effect of strain in the production of cold-worked iron and steel, and in the permanent record of the results of accidents straining structures—all these have been matters left for the present generation to investigate.

It is only to-day that we are beginning to ascertain the existence of alloys and special modifications of iron and steel which adapt these metals to special purposes, and the engineer is only now becoming accustomed to the writing of specifications including details of the composition and character of the materials to be used in his work. The use of manganese steels and bronzes, of the phosphor bronzes, and of various other deoxidized alloys, the search for the exact location of the alloy of maximum possible value for specified purposes; the continuation of researches in regard to the effect of prolonged loading of materials and of structures; these and similar matters are those which are receiving the attention of the engineer of our day, and are merely the beginnings of a *renaissance* in applied mechanics which is likely to reveal wonders where they have been least expected and most rarely looked for.

But the slow progress of scientific development in matters relating to common practice in the useful arts is hardly less remarkable than the difficulty with which

scientific principles, even when well established and well known among scientific and educated men, sink down into the minds of the masses. Perhaps no principle in the whole range of physical science is better established and more generally recognized than that which asserts the maximum efficiency of fluid in heat engines to be a function, simply, of the temperatures of reception and rejection of heat, and to be absolutely independent of the nature of the working fluid. This was shown by Carnot, sixty years ago, and has been considered one of the fundamental principles of thermo dynamics from that time to this. Nevertheless, so rarely is it comprehended by mechanics, and so difficult is it for the average mind to accept this truth, that the most magnificent fallacies of the time are based upon assumptions in direct contradiction of it. The various new "motors" recently brought before the public with the claim of more than possible perfection, have taken hundreds of thousands of dollars, within the past two or three years, from the pockets of credulous and greedy victims. It is not sufficient to declare the principle; the comparison of steam with ether, and of air or gas with carbon-disulphide or chloroform, must be made directly, and the results presented in exact figures, before the unfortunate investor —whose rapaciousness is too often such as to cause him to give ear to the swindler, rather than to the well-informed and disinterested professional to whom he would ordinarily at once go for advice— can be induced to withdraw from the dangerous but seductive scheme. It is true that the principle does not as exactly apply to a comparison of efficiencies of machine, and that the vendor of new motors usually seizes upon this point as his vantage ground; but a careful comparison of the several fluids, both as to efficiency of fluid and efficiency of machine, throughout the whole range of temperatures and pressures found practicable in application, such as has recently been made under my direction, shows that the final deduction is substantially the same for all the usually attainable conditions of practice, and, further, that of all the available fluids, steam is, fortunately, the best.

It is only since our political body became a nation that the application of scientific methods of experiment led that great engineer, James Watt, to the invention of the greatest of mechanical civilizing agents, the modern steam-engine. It is within the life-span of many who are still living that the art of spinning, the art of weaving by machinery, the production of the cotton gin, the invention of the sewing machine, and a thousand other now familiar and essential factors of our present life, have been born of this union of science and art. The locomotive, the steamship, the telegraph, the telephone, are all younger members of the same family—the mighty progeny of that mightier pair. The world has learned to value science for her beneficence, for her fruitfulness, for her helpfulness. It has learned that to a true union of science with art only, are we to look for the methods and the means by which mankind is to be finally, if at all, emancipated from the yoke of overburdening labor now so terribly oppressing the race.

The cultivation of science, in its relations to every branch of the arts, and to every department of the industries of the world; the collection of practically important facts, and the discovery of its essential laws, as forming a system of application of science, is, as is now sufficiently evident, the task which lies before every scientific worker. It is further evident that there must be inaugurated a *system* of cultivation of science that shall promote the advancement of scientific knowledge, and that shall aid in the application of science to the daily work of humanity. We have seen what such a system must be, and how it must be developed and set in operation. In the carrying out of this system of promotion and cultivation of science, we are to see that men of science are given all necessary assistance in their noble task; and the way in which this aid is to be obtained and made effective has been already discussed at sufficient length. But, when this part of our work has been satisfactorily organized and set in operation, we have the no less important task left us to see that the knowledge so acquired shall be preserved and communicated to the new generation. This leads us to consider our methods of education.

Glancing back into history, we find that the distinction which I have pointed out between the old and the new schools

of philosophy and of thought has been equally marked in the methods of education of the older civilization and the new. Only a few decades have passed since the only education that could be obtained in our schools was one embracing merely the purely literary and the speculative, with a small allowance of pure mathematics. The languages, history, literature, the elementary mathematics, and the old systems of speculative philosophy, were the principal subjects taught in our colleges. Gradually, the natural and physical sciences came in, and were given a subordinate place in the college course, and then only under protest. The stereotyped argument for the retention of the old system, to the exclusion of the new, was, and is to-day, the assertion that the old system strengthened the intellect and broadened the views of the student, while the new subjects were *merely useful*. The fact that the study of science is the most effective of disciplines for the reasoning faculties, for the memory, for the judgment, and for the very faculties for which the older instruction is claimed to do so much, is not even now perceived, far less admitted, by many of our most distinguished and ablest educators. But, in spite of all difficulties arising from ignorance, prejudice, habit and opposing interests, the study of applied sciences is becoming as well established, as part of the modern college course, as is that of any branch of pure science; and the study of pure science is very steadily becoming a more important part of the standard system of general education—of "liberal" education—while, at the same time, it is gradually becoming changed in its form of presentation, to adapt it more perfectly to its subsequent use in application. Speculation is everywhere losing its place, and investigation and systematic research are advancing to occupy the deserted ground.

The modern method of education is becoming thoroughly systematic. It involves the introduction of scientific methods of promotion of the efficiency of instruction; it includes the careful study of every detail of the educational system, and of the whole course of tuition, determining what methods are the most fruitful of useful and practically valuable results, what are the subjects, and what the methods of presentation, which give to the learner the largest amount of permanently retainable and widely applicable knowledge. Our primary education has always, and necessarily, been distinguished by the predominance of the scientific method and of the practical side. We have not been driven so imperatively toward this use of scientific methods, and of application of the sciences bearing upon common life, in the higher education; but the wisdom and the expediency of a modification of old ways, in this respect, is now rapidly becoming acknowledged, and the new education may be considered as fairly and safely introduced. We may call it the modern systematic method, the scientific method, of education. Science will never, we may be sure, displace entirely the older departments of education; but science will henceforth take a place beside them as no less valuable for mental discipline, and as the essential factor in the promotion of progress in all the arts and employments, in all the daily life and work of the world.

And not only may we feel assured that science will never entirely displace the older systems of education, although certain soon to take her rightful place beside literature and philosophy, and her own most efficient servant, mathematics; but we may plainly see that the time is not far distant when we shall have, for those who propose making science their mistress, and for those who are to make the work of their lives the application of science to the arts and the humbler industries of the world, "schools of science in every city, colleges of science in every State," and universities of science, pure and applied, as the base of the great pyramidal educational system. And it may be anticipated that when the system shall have become perfected and of full growth, it will be the universal custom of those proposing to study in these advanced schools, to secure, first, the general education, the broad culture, and the disciplinar preparatory training, that the academic schools now give, before entering upon the special branches of study that are to be continued through their later lives.

Students of science will enter these professional schools from the colleges of the country, precisely as they now enter the medical schools and the schools of law, making their professional studies

post-graduate courses. The line will thus lie through the primary schools, which are becoming each year better fitted to give the child the best introduction into a life either of labor or of study, through the higher schools, in which instruction is daily becoming more practically valuable, both in the imparting of knowledge and in mental discipline, through the college, where the discipline already given will make the student capable of securing good and permanently valuable knowledge, into the scientific school, and, in many cases, onward and upward into the university of sciences, in which all science is specialized for those who propose, as every scientific man must, to devote themselves wholly to scientific work.

Thus, ultimately, will science lead, direct, and most efficiently aid, the nation in its progress toward the ideal, yet approachable, social state which has been the hoped for, if not the promised, land of every great political and social economist and philosopher, from the days when Cicero thought it his greatest honor to have written "On the Commonwealth." up to the present time. According to Cicero, the Roman Commonwealth, "by defending its allies," took possession of the world. Our own grander commonwealth, by defending and sustaining her as yet hardly recognized, but most powerful and most beneficent ally, Science, will, some time, control, and for vastly grander purposes, a greater world.

The place of these modern methods in our political and social system can now be readily determined. Had it been asserted a generation ago that science should control our politics and dictate in every movement of our social system, and that it should be the guiding star of every political economist and of every philosopher, whatever his province, the claim would have excited a smile, and would neither have received consideration nor provoked rejoinder. But we shall see that this is precisely the place which will be ultimately, and of necessity, taken by science, and that it is to science that every great movement, whether political or social, industrial or ethical, must look for intelligent direction.

The object of every correct system of government is to secure to every member of the society which it guards protection of life and property, liberty to earn as much wealth and to secure as many of the comforts and luxuries of this life as he may, and opportunity to prepare the coming generation most effectively for successfully doing the work that lies before it. This is not the object accomplished by the old governments. They were established for the purpose of promoting the welfare of ruling individuals, or of ruling classes, and the result of their control of society was, invariably, the elevation of the one class at the expense of the other; the rulers flourished at the cost of those who were ruled. Modern systems of government are continually approaching that ideal form in which the people govern the people, and in which the public good and the security of the citizen is the end sought. But, as it is the end and aim of every good government to promote the welfare of the citizen by purely general legislation, and by the enforcement of laws enacted without reference to individuals or classes, it becomes the duty of the citizen who appoints the legislator, and of the legislator who makes the laws, to seek the scientific, the logically and the ethically correct, method of promoting general welfare. It is here that science, at the very start, becomes properly our guide. The government is charged with the duty of guarding and promoting every legitimate industry, of giving every citizen the means of preparing himself to do his work in the world and of developing, in every proper way, the natural resources and the appropriate industries of the territory over which it has control. How this can best be done it is the province of science to point out. Men of science, each in his own department, are the natural advisers of the legislator. Citizens and legislators are both entitled to claim this aid from those who have made the sciences of the several arts their special study, and from those who have devoted their lives to the study of the sciences of government, of social economy, and of ethics.

Of all the many fields in which the men of science of our day are working, that which most nearly concerns us, and that which is of most essential importance to the people of our time, is that department of applied science which is most closely related to the industries of the world. The two great needs of mankind to-day are, first, an education that shall enable the

workers to acquire all the necessaries of civilized life, a fair share of the comforts, and even some of its luxuries; second, such provision for the non-workers, deserving but invalid, willing but impotent, as shall insure them against actual suffering, and, if possible, give them some compensation, in the short remainder of life, for their misfortunes. By thus reducing the suffering existing in the world, science will accomplish its highest mission. Government has two main objects to secure: the suppression of crime and the promotion of industries. It is in the latter that applied science finds its plainest and its most obvious line of application, and in such application, as we shall readily perceive, the department of science which must find widest and most important fields of application will inevitably be that of "Mechanics."

Mechanics directs the advancement of the world in an astonishingly greater degree than does any other department of science, and it has, therefore, correspondingly great importance as one of the great agents of civilization. Every industry is largely mechanical; nearly all of the products of the labor of the world are given form, to a greater or less extent, and usually principally, by mechanism. It is applied mechanics that sows and reaps our grain, that grinds our flour, that transports it to domestic markets, that carries it across the ocean to the half-fed people of Europe; it is applied mechanics that prepares our cotton for the mill, that compresses the product of acres into a bale that may be handled by a single strong man, that spins our cotton and our wool, weaves them into cloth, and even cuts the cloth to pattern, and, by its most ingenious of minor applications, the sewing machine, gives the garment permanent form. Applied mechanics gives to the astronomer his telescope, enables him to calculate the elements of the planets and the stars, teaches the mariner his system of navigation, gives him the ship that he thus directs, guides the engineer in his magnificent work of designing the machinery which impels the enormous structure. Even the sister sciences, physics and chemistry, are departments of applied mechanics, and are coming to take their place in the wide spreading department of "molecular mechanics," and in a still more comprehensive but younger branch of our science—that of "energetics."

Even vital forces are gradually coming to be grouped under the same head, and all the natural sciences are more and more generally recognized as properly falling into the department of energetics, and as illustrations of the application of the laws of mechanics. The Mission of Science is to be fulfilled mainly, then, through the application of mechanics.

How the application of our beautiful and noble science is to promote the welfare of the race by the solution of the apparently abstract problems which everywhere challenge the student of science may not always be readily perceived. The mechanics of the ether, the determination of the exact measures of its elasticity and density—of which we only know to-day that the one is probably as enormous as the other is inconceivably small—the character of its vibrations, the method of distribution of its molecules, their magnitudes and distances, and the extent of their movements; the methods of conversion of mechanical energy, or of other forms of energy, into light and into heat; the great problem of transformation of heat into mechanical energy without waste; the still greater problem of the direct transmutation of the work of chemical combination into other forms of work and power; the discovery of the nature and method of operation of those forces which give rise to chemical and electrical energy; the method of conversion of the two forms of energy, the one into the other, with maximum efficiency; all these are problems that confront the investigator to-day, and all have, directly or indirectly, although it may not be easily seen just how, a real bearing upon the prosperity of the race. Those more directly "practical" problems, such as the discovery of a means of making non-conducting working cylinders for our heat-engines; the production of the electric arc without variation of intensity of light; the development of mechanical power with absolute steadiness and uniformity of speed; the concentration of power for aeronautic applications; the application of the mechanic's inventive power to the cheapening of all the methods of production and supply of the perishable necessaries of life; all these are obviously within the province of our

science in the prosecution of its beneficent mission. But it is not enough that it shall be made possible that one pair of hands shall do the work of two; work must be found in new fields for the pair of hands thus thrown out, and this makes it the duty of science and of its workers to see that new departments of skilled employment shall be opened to surplus labor. Thus the development of new industries becomes as much a part of the work of science in the future as is the improvement of those now existing. The new industries must evidently be mainly skilled industries, and must afford employment to the more intelligent and more finely endowed of those to whom our modern systems of education are offering their best gifts. When this process of industrial revolution shall have been effected, the great mass of mankind will be able to secure by the labor of each day, restricted to such number of working hours as shall best develop and maintain in healthy condition the whole muscular system, all the necessaries and comforts of civilized life, and will yet find time for recreation and for the cultivation of the moral and intellectual faculties, and for the development of all the mental powers and of all the affections.

The progress of science, as seen in her past history, resembles that of the great steamships which are now the embodiment of the most wonderful of the results of human intellect, working through the scientific application of mechanics, which to-day mark the advanced position of civilization. In the building of the steamer long weeks are spent in the preparation of plans, in the calculation of proportions, and in the determination of the form in which the enormous masses of iron are to be grouped; months are spent in gathering the materials together which are to be given shape in the great vessel, and which are to be turned and planed and cast and forged into the pieces composing the mighty engines and lesser machinery; during months and months the tremendous structure lies motionless upon the ways, slowly taking shape, slowly receiving the massive machinery which is to form the vital apparatus essential to the life-like action of that powerful, and hardly less than living, creature; no sign of life or power is seen during this long period of development, and, to the uninstructed observer, it may appear utterly improbable that the dormant mass can ever be more than an inert and useless hulk; yet, after a time, when the period of preparation is completed, and when all that is needed for the purposes intended by the designer and the constructor has been brought together and put in place, suitably connected, part to part, there comes a time when a change and a movement are perceived. A few insignificant pieces of timber are knocked away, and the enormous vessel, slowly and by imperceptible acceleration, moves down toward the water, and, with continually increasing speed, finally rushes into the element which is to be, for all its future life, its home. A halt and a little more delay, and the now fully equipped and self-impelling steamship once more moves. Starting again, with slow and hardly visible motion, by the exertion of her own unseen, but inconceivable power, the great ship gradually acquires velocity, and we see her, later, traversing the ocean, back and forth, over a thousand leagues of water, like an enormous shuttle, weaving bands that tie closer and closer hitherto separated members of a common race, of one human stock, and binding the nations daily into more perfect brotherhood.

So it was with science in the past, and so is it in the present. Long ages ago, in the earliest historic period, was her time of slow and unobserved generation and embryonic growth. All through the middle ages signs were not wanting of her existence and gradual development, in the changing methods of thought of mankind, and in the accumulation of materials to be usefully applied at a later date. At the beginning of the seventeenth century, the first great movement began, and then only did the true purpose of all that earlier period of preparation become evident. A century ago, with the birth of the steam-engine, later, with the introduction of product of the printing press into the daily life of the world, with the apparition of the electric telegraph and the introduction of the railroad, began the real progress of science, and we are now seeing but the beginning of her awe-inspiring career. She has taught us to drive ten thousand tons across the seas, regardless of wind and waves, by the might of our 12,000 horse-power engines

—engines in which steam does more work than fifty thousand actual horses could do, continuously. She has taught us to send printed messages across the oceans and across the continents, girdling the world with her mysterious wire; she has shown us how to drive the railway train, with its hundreds of tons of merchandise and living freight, faster than bird can fly; she has helped us give to the people news of every land, gathered in every clime, and brought to us by messengers swifter than the shadows of the sun, and printed on millions of sheets between the first glowing of the dawn and the rising of the orb of which Aurora is the messenger; she has given practical expression to a myriad of other hardly less magnificent philanthrophies. Yet the mission of science has made but the veriest beginning. It still remains to her to perfect and to systematize a thousand new industries, to invent as yet unimagined new arts, to bring the laborer worthy of his hire all that he needs, and all that he can desire for his own comfort and for the care and comfort of his family, to so adjust the power of production to that of consumption, and both to the working capacity of the world, that the now seeming natural conflict between the employer and the employee, between labor and capital—that fallacy which is the support of every demagogue—shall no longer have even the appearance of existence. She has still to do her part toward the reduction of all systems of government to the one only correct form; that in which the people are governed by the people. for the best good of the people, and in which legislation is solely directed toward the protection of life, of liberty to do right, toward the protection and support of the industries of the country, the sustaining of a system of education that shall give to every citizen the opportunity to fit himself with maximum efficiency for the duties of a well planned life, and the encouragement, in every right and reasonable way, of all that tends to aid the material and the moral welfare of the community.

She has all this and much more to do; and her highest work will be found to include, I think, important modifications of the methods of evolution and of conformation of the race. The enormous advancement of the intellectual side of life must inevitably, as it seems to me, result in the production of a race of men peculiarly adapted to such environment as science is rapidly producing. Thus accomplishing, under the guidance of our science, such tasks as lie before him to accomplish, the "Coming Man," with his greater frontal development, his increased mental and nerve power, his growing endurance and probably lengthening life, will be the greatest of the products of this scientific development, and the noblest of all these wonderful works. And may it not be possible in the better days of that future into which we may now barely get the faintest glimpse, when the increase of the population of the world shall be limited, not as now by the maximum of misery and suffering bearable by the race, nor yet by art, not by a Malthusian system, but by the rate of expenditure of vital power in the operations of the mind, of the intellect, and of the affections, when those who are brought into the world shall have fair prospect of being permitted to lead happy and prosperous lives, when suffering and misery shall have been reduced to a minimum—that we may see man taking the place assigned him by Ruskin? Says that great master of expression: "All the power of nature depends upon subjection to the human soul. Man is the sun of the world; more than the real sun. The fire of his wonderful heart is the only light and heat worth gauge or measure. Where he is are the tropics; where he is not, the ice-world." May not this development of the human soul be, after all, the true Mission of Science?

As a toil-worn traveler, wearily faring homeward at early dawn, skirts the western shore of some broad lake, picking his way by the uncertain, but always increasing, light penetrating the cloud beflecked sky, at last sees in the east the uprising sun, and watches its steadily growing disk, and the wide-extended sheaves and pencils of splendent golden light, silvering and gilding, and magnificently tinting, every snowy pile of vapor, etherializing all the low-lying mist that hides the bosom of the lake, and sees finally, across the rippling waves stirred by the first gentle breezes of the dawn, the flashing of a broad band of glory, each wave at the distant shore catching up its share of the wonderful illumination, each its handful of the beautiful light, each passing it

onward to the nearer swell, and each catching new beauty from the passing beams of the day-god, until the eyes are dazzled by the spreading sheen, and all the scene is surcharged with light, until the glory covers the weary one, lightening his heart, cheering his soul, quickening his step, and sending him homeward, with all his sadness gone, refreshed, hopeful, and happy.

So Man, plodding onward, sad, overburdened, and despairing, toiling wearily over the shifting sands of life, at last has seen, across the expanse of eternity, along the shores of which he wanders, the first bright beams of the light of Science, heralded, but hidden, through a dawn that had lasted for centuries; and, as the bright luminary that is to guide him through all the future, has arisen, steadily and constantly, among the obscuring, but breaking, clouds of the dark ages, the mists have been dispelled, the clouds themselves have received golden and silver linings, and the all-pervading beams, caught and reflected, but always advancing, have finally reached the hither shore, and Man, enlightened and strengthened, with new insight into a brightening life, himself advances, with new courage and renewed hope, toward that future which it is the heaven-directed Mission of Science to illumine with the radiance of ever-increasing knowledge.

CHINESE IRON FOUNDRIES AND RICE PAN CASTINGS.

From "The Chemical News."

Although the Chinese, as a race, are incapable of the deep thought and extreme mental effort required to elaborate the intricate details of modern scientific machinery, or to plan those bold enterprises and extensive systems of road and hydraulic engineering which are the pride and glory of the British civil engineer, yet, *per contra*, it must be conceded that for finnicking, tedious, patient ingenuity of a certain sort, the Chinaman stands almost without a rival. As a notable example of this same patient, plodding ingenuity, shown by the Chinaman in some of his trades and industries, may be instanced the manufacture of the very thin cast-iron rice pans which may be seen in almost any cook-house in the colony of Hongkong. The principle seats of this industry are at the towns of Sam tiu-chuk, in the Kwei-shin district of the Wei-chow prefecture, and at the busy, populous, manufacturing town of Fatshan, situated in the Nam-hoi district of the Kwang-chow prefecture. This latter town is distant but some twelve miles, in a south-westerly direction, from the provincial capital of Canton, and has, from the extent and importance of its trade and manufactures, notably its great trade in iron goods, tools, and hardware, been aptly termed the Birmingham of China. The previously mentioned town of Sam-tiu-chuk is inhabited principally by Hakkas, and is one of the principal towns of the sparsely populated and mountainous district of Kwei-shin. The iron used is obtained by smelting the magnetic oxide, which is found in large masses in the mountains surrounding the town. The ore is broken up, and smelted with charcoal in a primitive smelting furnace or cupola some eight feet high; the cupola is cone shaped, having its apex, or smaller diameter, at the bottom; the single tuyere pipe is of earthenware, the opening for emission of the blast being placed downwards. The furnace itself is of earthenware, or rather puddled and dried clay, kept from falling to pieces and strengthened by hoops and longitudinal straps of iron; the whole is lined with clay several inches thick; the internal diameter at the bottom may be about two feet, or perhaps a little more, and at the top about three feet and a-half, inside depth about six feet. The blast is produced by a rude yet most ingeniously contrived bellows, formed of a wooden box some five feet long by three feet in horizontal and a foot and a-half in vertical section. This box is divided longitudinally into two compartments, each eighteen inches square in vertical section, in each of which compartment a piston works; the

valves are so arranged that one piston is effective in the up, the other in the down, or rather return stroke, for the machine is arranged horizontally. It will be seen, however, from this arrangement, as there is no air chamber, that the blast is not perfectly continuous, there being a slight cessation at the end of each stroke before the return stroke can be effective. The fuel used is charcoal, and the furnace, being first heated by starting a fire with fuel alone, is then filled up with alternate layers of charcoal and ore in small fragments. The blast is urged, and after a sufficient time has elapsed, the molten metal is drawn off from a tap hole at the bottom in the usual manner, and cast into ingots, which, when intended for export, are afterwards reheated in an open forge, and beaten into blooms of about six pounds in weight; these may occasionally be seen for sale in the iron-dealers' shops in Hong-Kong, and, when made from genuine native iron, fetch a very high price, indeed, as much as four dollars per picul, or even more, being sometimes paid for the best quality made from the black or magnetic oxide. The Fatshan iron, which, to a great extent, comes from Ying-tak (a town on the West River), is smelted from hematite (the red oxide), but mixed to a considerable extent with gangue, rarely pure, and of varying and uncertain chemical composition. The iron smelted from this latter ore, although far more valuable in the native estimation than foreign imported iron, yet does not realize so high a price in the market as the other.

For making the very thin rice pans, which are cast without handles, pure native iron alone can be used; as being smelted with charcoal, it has the property, when melted, of being more fluid than iron smelted with coal; or it may be that the iron itself, being uncontaminated with sulphur, or phosphorus, possesses the property of greater fluidity on this account. The moulds in which the pans are cast require weeks of tedious and patient labor to bring them to perfection. They are composed of two parts—an upper and a lower—and are made of carefully puddled clay, the upper portion about an inch and a half, and the lower somewhat thicker; the lower or under half is full of round holes, about half an inch in diameter, which pierce about two-thirds the thickness of the mould; these holes are made in order to allow the clay to dry thoroughly; the moulds are turned true on a revolving potter's table of the usual pattern, and when quite dry receive a final coating of fine moulding sand, and are made perfectly smooth. The two portions of the mould are then luted together with clay and placed in a large round oven some six feet or more in diameter. The pans are cast bottom upwards, each mould having a runner but no riser; the upper portion of the mould has three little legs in order to support it when drying previously to the two moulds being luted together. After being placed in the oven, which is some two and a-half feet deep, the moulds are surrounded with charcoal, which is fired, and the ovens closely covered with a curiously constructed earthenware, or rather dried clay cover, kept together, as in the case of the furnaces or cupolas previously mentioned, with bands and straps of iron. The process is so timed, that by the time the moulds are at a bright red heat, or almost white heat, the iron in the cupola is melted, and ready for tapping; the molten metal is then run out into ladles made for the purpose, and quickly poured into the moulds. When these are all filled, the cover of the oven is readjusted, and the whole left to anneal or cool gradually.

The great secret about this process, which enables the Chinese founders to cast their iron pans of such large diameter, yet so thin and light as to be scarcely thicker than a sheet of paper, appears to be the use of highly heated moulds, and pure iron smelted with charcoal. When the ovens and their contents are cooled down, which takes about two days, the luting attaching the upper portion of the mould to the lower is carefully removed, and the moulds being separated, the pan can be extracted; when the operation has been successful, the same mould can, with a little touching up, be used several times. The pans now have each attached to its bottom a runner, or lump of iron, of greater or less size, which, from the extreme thinness of the pans, making them but little less brittle than earthenware, requires the greatest care in its removal; these runners are carefully sawn off, the use of the more expeditious cold chisel being more

likely to cause fracture than the slower but steadier saw; the edges are smoothed down, and the pan is ready for the export market. Handles are attached to these pans by the retail dealers, who bore holes near the rim of the pan, and attach small ribbons of iron for the purpose of handles.

The pans made at Fatshan differ from the preceding in being cast with handles attached near the rim to the inner surface of the pan, which necessitates the breaking of the mould at each casting, it being rare for the same mould to be serviceable a second time. The Fatshan pans are also usually cast much thicker and heavier than those of Sam-tiu-chuk, and occasionally as large a proportion as one-third of foreign cast iron, generally Kentledge or ordinary pig iron, is mixed with the native iron for casting. In other respects the process followed at both places is the same. The Fatshan pans being thicker are the more durable of the two, while the thinner Kwei-shin pans are more popular with poor people, because being thinner a less quantity of fire-wood is required to heat them through. The manufacture of iron rice pans is in Kwangtung province a Chinese Government monopoly, which is farmed out by the Salt Commissioner, and by him licenses are granted to the local iron founders on payment of a heavy fee. Considerable care has to be used in packing the pans for export, in order to prevent breakage, which, however frequently occurs when any considerable number of pans are shipped to Australia or other distant ports. An attempt was made, some years back, to cast rice pans in Hongkong, but the locality chosen, Shau-ki-wan, being an unhealthy one, many of the workmen died, others left the place sickly and fever stricken, and the concern from this cause mainly proved a failure. It may, however, be possible that had a longer time, say a year or more, been allowed to elapse for the newly filled-in ground to settle down, and the freshly cut hill side adjacent to finish giving off its malarious exhalations, the place would not have been so unhealthy, and in that case the result might not have been so disastrous to all concerned, as it unfortunately proved itself to be.

ON THE PRACTICAL RESULTS OBTAINED FROM VARIOUS WATER-RAISING MACHINES IN HOLLAND.

By G. CUPPARI.

From Selected Papers of the Institution of Civil Engineers.

Towards the end of the year 1877 the Author visited Holland, and spent a year and a-half in studying the hydraulic works in that country, particularly those for draining land. Having had opportunities of examining the principal works, both finished and under construction, and of taking notes from various documents referring to them, he collected a large amount of information not otherwise procurable.

In the specifications for water-raising machines in Holland, a clause is inserted to the effect that the consumption of Ruhr coal is not to exceed 6.61 lbs. per H. P. per hour. In practice, however, there are great differences in the duty of the engines.

The Rhineland Company. Pumping Station at Halfweg.—This station was erected for the purpose of discharging into the Y (which was converted into a canal in 1873) the waters of the general collecting basin of the great Rhineland Company. The surface of this basin (called "boezem," a Dutch word which will be used throughout the Paper) covers 8,600 acres, when the water is standing at its normal level. There discharge into this basin, naturally, the high lands, 30,443 acres in extent; artificially, the polder lands. These are classified according to the normal water-levels as follows:—

	Acres.
Normal level at 3.28 feet—AP and over	16,282
" bet. 3.28 ft. and 5.0 ft.—AP.	60,855
" " 5.0 " 6.5 "	22,314
" " 6.5 " 11.5 "	0
" " 11.5 " 13.1 "	3,249
" " 13.1 " 14.75 "	3,874
" " 14.75 " 16.4 "	66,029
" " 16.4 " 18.0 "	6,731
" " 18.0 " 19.7 "	7,882

These areas vary year by year in Holland, owing to the increased drying up of the land, the variations in the normal level, &c. The above are the figures for 1867, since which date there have been no changes of importance. The total area of Rhineland is 258,382 acres, but it also receives into its boezem the waters of the Woerden Association, of which the boezem area is 403 acres, and the total area draining into the boezem of Rhineland is 302,590 acres.

When the lake of Haarlem, which was in communication with the boezem of Rhineland, was drained the great diminution in the receiving basin was compensated by providing a better outlet into the North Sea at Katwijk, and three pumping-stations, at Halfweg and Spaarndam on the Y, and at Gouda on the Yssel. In 1880 another was added at Katwijk. The waters discharging into this receiving basin, composed of a network of canals and small lakes, come for the most part from the polders, that is to say, the discharge is performed mechanically. But this first lift is generally insufficient, and a second is required, which is effected by steam pumping-engines.*

The internal conditions of the boezems are,

Mean water-level (1873-7)	1.656 feet—AP.
Minimum " "	2.297 "
Maximum " "	0.656 "
The maximum should be	1.312 "

The levels of the Y previous to its canalization were at Halfweg,

	Feet.
Mean high water	0.26+AP.
" low "	0.82−AP.
Maximum high water	6.62+AP.
Minimum low "	3.94−AP.

After the closing of the Y, the canal which took its place was to be maintained in terms of the concession at 1.64—AP. This level remains simply a desideratum as far as Rhineland is concerned, while during the past year the mean level of the canal at Halfweg was 1.20—AP. The last pumping station was intended to control the internal levels, in which the difference of a few inches might cause incalculable damage; the maximum ought never to exceed 1.31 ft.—AP.

The Halfweg pumping station has six float-wheels, of a combined width of breast of 38.70 ft. The external diameter of one of the wheels is 23 ft., that of the other five, 21.33 ft.; the internal radius is 5.92 ft. The floats, twenty-four in number, are inclined to the radius, so as to be tangential to a circle concentric with the wheel, and having a radius of 2.85 ft.; the center of the wheel is at 5.6 ft.+AP. The steam-engine has four separate valves, with expansion regulated by hand (of the old double-acting Cornish type); the cylinder is 3.33 ft.×8.0 ft. There are three boilers always in steam, having each 538 square feet of heating surface. The maximum pressure is three atmospheres. The driving axle is connected by toothed gearing on each side to a shaft carrying three wheels; the speed is reduced in the ratio of 13.5 to 6; the wheels are all upon the same shaft, but this is not all in one piece, but in several, which can be coupled up as required.

There are three systems of construction of water-wheels, which differ in the method of transmitting the force. In the first system the force is transmitted by a driving axle and spokes acting as struts; in the second by a toothed wheel upon the circumference, the axle and spokes acting as struts; in the third, by a similar toothed wheel, but with a double set of rods in tension instead of spokes. The Dutch still adhere to the first system, although, according to Redtenbacher, it is not suitable when the power exceeds 10 or 12 H.P. With large wheels it is very heavy; thus, the Italian wheels at Bresega, near Adria, which are on the the third system, have an external diameter of 39.4 ft., an internal diameter of 26.25 ft., and a breadth of 6.56 ft.; there are no larger wheels than these either in Holland or Italy. The displacement of water is about 5,300 cubic feet per minute per wheel. The axle of these wheels has a diameter at the thickest

* In 1881, there were discharged from the boezem 21,825 millions of cubic feet of water, of which 12,587 millions were raised by machinery; 2,684 millions cubic feet were let into the boezem, the greater part in summer to supply the canals.

part of 1.41 foot, and 1.25 foot at the bearings. The wheels at Katwijk, which are on the first system, are only 29.5 ft. in diameter, yet the axles of the furthest wheels are of the same diameter as above.

At Zeeburg, near Amsterdam, there are eight wheels of the most recent construction, of 26 ft. 3 in. diameter, and 10 ft. 8 in. breast. The driving axles of the wheels furthest from the motor are 1 ft. 6 in. in diameter, and weigh over 6 tons; each wheel has four sets of spokes, each set weighing 4 tons; the driving axles nearest the motor weigh nearly double; there are 282 cubic feet of oak, and 222 cubic feet of pine timber in each wheel. Compared to the mass and weight of material, the volume of water raised, amounting to 7,063 cubic feet per minute per wheel, seems small. The velocity of the periphery is about 208 feet per minute, which in Holland is considered moderate, but in Italy high. In this system of construction the axle is subject both to bending and torsion; in the suspension system to bending only.

Mr. Zangirolami, of Adria, constructs wheels with curved buckets capable of raising water to $\frac{4}{5}$ of the radius, giving excellent results. Instead of two toothed wheels, one at each side of the wheel, he puts one toothed wheel in the middle, thus avoiding the practical difficulty and expense of two cogged wheels of precisely similar pattern on the one hand, and the twisting effect produced by a single cogged wheel when placed at one end of the wheel on the other.

At Halfweg the driving-axle is of cast-iron, solid, 1 foot 2 inches in diameter near the motor, and 10 inches at the further end, with enlargements at the joints. The framework of each wheel is formed of three sets of spokes, which are cast in one piece with the nave and ring, or rather each set is cast in two parts and bolted together. The whole weight of one wheel with its axle is probably about 15 tons.

Tables are given of the work performed by the wheels monthly during the years 1872–5. The first table gives the number of revolutions per minute, the number of hours worked, the volume of water raised, the lift, the effective HP., the consumption of coal in each month, and per HP. per hour. The second table shows how the duty of the engine increases with the lift. When the lift was from 8 inches to 1 foot, the consumption of coal per HP. per hour averaged 14.20 lbs.; when the lift was from 1 foot to 1 foot 4 inches the consumption averaged 11 lbs.; when the lift was from 1 foot 4 inches to 1 foot 8 inches, the consumption averaged 8.8 lbs., and when the lift was from 2 feet to 2 feet 3½ inches, the consumption averaged 5.5 lbs. per HP. per hour.

This difference is accounted for by the large amount of power required simply to drive the wheels themselves. This being a constant quantity, is much greater in proportion when the work expended in raising the water is small. It would be useful to have experiments on the performance of the engines when simply turning the wheels, but, failing such experiments, the author gives instances in which the lift was very small. On the 16th of March, 1876, with a lift of only 0.45 of a foot, all the six wheels were at work for 495 minutes, and made 2,043 revolutions, the immersion of the wheels at the time being 3.75 feet on the low-water side. Applying the recognized coefficient for similar wheels of 0.90, the volume of water raised was estimated at 30,000 cubic feet per second. The useful effect was therefore 25 HP. The total consumption of coal was 10,493 lbs., or 50 lbs. per effective HP. per hour.

General Delprat investigated experimentally the working of a somewhat similar establishment with six paddle-wheels for eighty days, with lifts varying from 0.033 of a foot to 1.75 foot. He found that the useful effect, when the lift was a minimum, was only 3 HP., while the work corresponding to the *vis viva* of the water issuing from the wheel was 69-.24 HP. With the maximum lift, on the other hand, the former was 130.05 HP., the latter only 19.57 HP. The sum of the two kinds of work, useful effect, and work corresponding to the velocity, was 72.24 HP., with the lift of 0.033 of a foot, and 149.62 with the lift of 1.75 foot. This sum rather more than doubled, while the lift in the last case was fifty-three times that in the first, and the useful effect in water raised was about forty-three times as great.

These wheels, therefore, besides being very costly, have the disadvantage that, as the inner water-level diminishes the

discharge also diminishes, while the number of revolutions remains constant. If, then, this reduction in the inner water-level is accompanied with a reduction of the lift, the conditions of useful effect are still worse. The six wheels at Halfweg, which with an inner water-level of 8 inches—AP (the highest), give a discharge of 8,263 cubic feet per revolution, give only 5,510 when the water is at its lowest level of 2.46 feet—AP.

Hydraulic Station at Katwijk.—This was erected in 1880 to regulate more completely the waters of the Boezem. The levels of the external water are:—

	Feet.
Mean high water.....	2 93+AP.
" low "	2.72—AP.
Maximum high water.....	11.48+AP.
Minimum low "	6.56—AP.

The distance of the buildings from the sea is 2,000 feet.

This station and that at Zeeburg, near Amsterdam, intended for changing the water in the canals in that city, are the two largest of recent construction in Holland. In both the system adopted is similar to that at Halfweg. At Katwijk there are six wheels, each 29 feet 6 inches in external diameter, and 8 feet breast The centers of the wheels are at 8 feet 3 inches above AP., the sill of the channel is at 1.64 foot—AP., which is the mean level of the surface of the internal water. The number of wheels at work can be regulated by gearing. The weight of a single wheel with its axle is estimated at 41½ tons. The selection of this system shows that it is considered the one best adapted to the conditions at Katwijk. Flat buckets have been adopted as being the best under the conditions, namely, a lift varying daily (with respect to sea-level), and averaging from 0 to 4.5 feet, with an ordinary maximum of 6.89; the fluctuation of the internal level being very slight, the greatest difference in the year 1881 being 1.60 foot, and the greatest in a month being 0.82 foot. There is no doubt that the differences will be still smaller with the new lifting wheels at work. The manner in which the variations in internal water-level are kept within very small limits is one of the remarkable features in the Dutch system.

The buckets of the wheels at Katwijk are tangential to a circle concentric with the wheel, and having a radius of 5.25 feet. The effect of this is that with the internal water at its mean level, and the external at mean high-water level, the angle of ingress is about 20° 30′, and that of egress 42°. The proper diameter of this tangential circumference is a subject much discussed among Dutch engineers. This, together with the radius of the wheel, and the position of the axis, determines the angles of ingress and egress, upon which the effect of the wheel greatly depends. Inspector J. A. Beijerinck, the celebrated engineer of the Zuidplas and Haarlem reclamations, and the author of the first really practical project for reclaiming the Zuider-Zee, has devoted considerable attention to float-wheels and screw-elevators in a monograph on the Zuidplas, which will be referred to later on. He upholds the rule that the angles of ingress and egress of the paddles with the mean internal and external water-levels should be equal; which, when the radius of the wheel is known, readily gives that of the circumference to which the paddles are tangential, by means of a simple geometrical construction. This has long been a general practical rule, and is still frequently followed, though the desire for innovation has given rise to others, perhaps too many.

If α is the angle of ingress, β that of egress, H_i H_e the depths below the axis of the wheel of the internal and external levels, Δ the lift, R the radius of the wheel. ρ that of the above-named circumference, we have

$$H_i = R\left(\sin\alpha\sqrt{1-\frac{\rho^2}{R^2}}+\cos\alpha\frac{\rho}{R}\right)$$

$$H_e = R\left(\sin\beta\sqrt{1-\frac{\rho^2}{R^2}}-\cos\beta\frac{\rho}{R}\right)$$

$$\Delta = \sqrt{R^2-\rho^2}\,(\sin\alpha-\sin\beta) + \rho\,(\cos\alpha+\cos\beta).$$

Of the quantities H_i, H_e, R, α, β, ρ, any three can be found when the other three are known, according to the theory of hydraulic wheels, by equations which correspond to the minimum for the loss of work due to various causes. This loss being expressed in terms of the remaining independent variables, including in these the velocity, which is another very important element, there will be enough equations to determine all the unknown qualities. In practice they are given by rules. One is that already given, from which

$\Delta = 2\rho \cos. a$. Some authorities make it a rule that the value of a shall lie between 20° and 30°. Since, if the immersion i of the buckets is known, $R = H_i + i$, the value of R depends upon that of i, which is generally beetwen 3.25 feet, and 4.87 feet, according to the difficulties of foundations and construction. Some maintain that the ratio $\frac{\rho}{R}$ must lie between $\frac{1}{3.5}$ and $\frac{1}{4}$. Others state that H_e must lie between $\frac{1}{4}$ and $\frac{1}{5}$ of R, but the principal rule, and that most generally adopted. is that of the equality of a and β. At Katwijk, however, this rule has not been adopted. At the maximum daily level the angle of egress is nearly double that of ingress, which is 20° 30'. At the mean level it is more favorable, increasing by about 6°. There seems very good reason for departing from the established rule.

It is true, indeed, that by improving the ingress the egress suffers, but in a very different degree. R being given, a and β can be expresssed by a single variable, the angle Φ of the paddle with the radius. The loss at the ingress will be a certain function $f_i(\Phi)$, that at the egress $f_e(\Phi)$, indicating by f_i and f' two different functions. The variable Φ will be determined by the condition that $f_i(\Phi) + f_e(\Phi)$ shall be a minimum. It would be difficult and almost useless to determine mathematically the expression of that sum as a function of (Φ). It is certain that for a given variation of Φ the gain on one hand is very different from the loss on the other, and that it is better to increase the angle of egress. If this is too small, there is a useless heaping up at the discharge, which may be a very considerable part of the lift, or may even exceed it, and the rule of equal angles often places the wheels under unfavorable conditions.

The Katwijk wheels are driven by two compound engines supplied with steam from eight Lancashire boilers, with double fire-boxes, each 32.8 feet × 7.31 feet, with seven Galloway tubes. The heating-surface of each boiler is 970 square feet. It was specified that with a working pressure of 5 atmospheres the eight wheels should raise—

	Feet.
4,238,000 cubic feet per hour with a lift of	4.10
3,532,000 " " "	5.27
2,825,000 " " "	6.88

so that the maximum useful effect should be 615 H.P.

On the trial of the engines, the number of revolutions varied from 3.93 to 4.54 per minute. The most convenient for ordinary working is 4, corresponding to 36 revolutions of the fly-wheel, the velocity at the periphery being 7.22 feet per second. The ratio of useful effect to indicated power varied from 33 to 70 per cent., the average being 50. It is expected that a higher value will be obtained after the engines have been in use a little while, and the gearing has become eased.

The principal dimensions of the buildings are:

	Ft. Ins.	Ft. Ins.
Engine-house, inside	59 0	× 49 3
Boiler " "	93 8	× 65 3
Each of the covered chambers for the wheels	44 9	× 39 4
There are two chmneys 85 ft. high above the fire-grates, with an internal diameter of	6 3	
Coal-store	164 0	× 32 9

The cost of the establishment, exclusive of earthwork in the canals, was

	£.
For the buildings, about	15,000
" machinery "	14,200
Total	£29,300

Pumping Station at Gouda.—The external water-levels (of the Yssel) are—

	Feet.
Mean high water	3.64 + AP.
" low "	0.55 − AP.
Maximum high water	10.06 + AP.
Minimum low "	4.26 − AP.

When the station was established, in 1857, six paddle-wheels were erected, which in 1872 were changed to wheel-pumps, of which the axis was at 7.21 feet + AP, the lowest part of the drum at 2.50 − AP, that of the buckets 5.78 feet − AP. The total available width of breast was 31.17 feet. In 1873 two of the buckets, of which there were only six, broke, and in repairing them the number was increased to twelve. Under the direction of Professor Henket the buckets were made of a curved form, with the concavity towards the inner water. Since then repairs have been effected by Mr. Rijk, who introduced curves with the concavity towards the outer water, the curvature being that of a logarithmic spiral. At one time three varieties of buckets were in use at the same time on these wheels, three having Mr. Rijk's

form, one that of Professor Henket, two nearly flat. It was evident that the difference in the delivery was slight; Rijk's system was on the whole preferable.

The steam-engine here is of the same class as that at Halfweg. The cylinder is 3.65 feet × 8 feet. There are three Cornish boilers, each having 883 square feet of heating surface. A table is given showing the performance of the engines during the year 1877, from which it appears that, omitting the months of January, April, and May, when very little work was done, and the lift was small, the consumption of coal was 8.6 lbs. per HP. per hour. Under the same circumstances the Halfweg engines and wheels would have given much better results. In the calculation, the loss of water by slipping and by the partial filling of the buckets, was taken at 15 per cent., which is too little. Some experiments gave 22 per cent. for this loss.

General Association of Delfland.—The total area of Delfland, which ranks next in importance to Rhineland, is over 74,000 acres. Its boezem* is relatively very small, about 954 acres. Its conditions in regard to drainage have always been, and still are, worse than those of Rhineland. Besides the small area of the boezem, the natural discharge into the rivers is attended with difficulty, and there was no artificial means of discharge until 1864, when a station was established at Vijfsluizen, upon the Meuse, not far from Schiedam.

The levels are as follows, referred to the Delfland datum, D. P., which corresponds to 1.071 foot below AP.:—

Internal waters	Minimum	0.82 − DP.
	Maximum	0.66 + DP.
External waters	Mean daily high water	4.00 + DP.
	" low "	0.07 + DP.
	Max. high water, about	7.02 + DP.
	Min. low "	1.74 − DP.

The water is discharged naturally whenever the levels admit. There are six wheels, disposed symmetrically with respect to the motor, of 26.24 feet external, and 12.47 feet internal diameter. The width of breast is 4.92 feet. They work up to 5.38 + DP. The axis is at 8.35 + DP. The radius of the tangential circle is 2.75 feet. The system of construction is similar to that at Halfweg. The engine has a single cylinder 3 ft. 4 in. × 8 ft. 3 in.; the ratio of transmission is 11 : 4.4. The normal velocity of the wheels is 4.4 revolutions per minute. There are three Cornish boilers, 33 ft. × 6 ft. 6 in.; the maximum pressure is 3 atmospheres.

A serious defect in the action of float-wheels is the great diminution in discharging power as the internal water lowers. At Vijfsluizen, for instance, with the inner water-levels at 0.66 − DP, zero, and 0.66 + DP, the volumes of water discharged are respectively 1,092,481, 1,263,133, and 1,421,845 cubic feet, that is to say, that the volume varies from 3 to 4 for the above limits of water-level. The following are the results of two years' working. The year is reckoned from the 1st of May:—

1874–5.—Total number of hours worked, 807. On only thirteen days was water raised continuously during twenty-four hours. The longest stretch of work was 120 hours. The engines were worked so as always to give a useful effect of 104 HP. The consumption of coal was 7.075 lbs. per HP. per hour, including that used for getting up steam and banking the fires while the engines stopped for short periods.

1876–7.—Number of hours in work, 2,086. Continuous work throughout the twenty-four hours on twenty-eight days. Consumption of coal 6.90 lbs. per HP. per hour.

These results, though deserving of record, are not entirely trustworthy, as

* Both as regards the internal waters in the dykes and canals, and the external waters in the boezems, the conditions are usually expressed by the ratio between the water-surface at the normal level and that of the whole polder in the former case, and that of the entire group of polders forming a general association in the latter. Thus the water-surface of the boezem of Delfland is $\frac{1}{7.7}$. Each of the separate polders has its own ratio to the internal waters. These two ratios are quite distinct, and express relations which for new undertakings are determined by very different standards. In the case of the polders the ratio depends upon the power of the water-raising machinery, in that of the boezems, upon the régime of the discharge into natural receivers, rivers or sea, subject to tidal action. When wind was the only motive power, this sufficed to drain the polders, but not as a rule the boezems. For them, therefore, the ratio depended generally solely upon the régime of the natural receivers, upon the duration and extent of the ebb tide, and upon the maximum heights which could be given to the banks of the canals belonging to the boezems. For the polders, therefore, the works had to be so arranged that with the ordinary winds, taking into account periods of calm, the land could be kept as far as possible from submersion. The wind-mills had to stop working when the wind failed, and also whenever the water-level in the boezem attained a dangerously high level. With the introduction of steam all these relations were naturally changed. In the case of the boezems the regimen of the receivers still remains a most important consideration, as the greater part of the water must be discharged by natural means.

they are founded upon the hypothesis that the useful effect is constant.

Mastenbroek Polder.—This pumping-station is interesting from the fact that in 1878 three wheel-pumps were erected there, which had been very carefully studied by two engineers of very high standing, Professor Henket and Mr. Backer. These engineers studied the subject with reference to both float-wheels and wheel-pumps, and left the choice to the constructors, the work being let by tender.

These wrought-iron wheel-pumps were of a very different form from that proposed by the original inventor. The specification stated that the diameter of the drum was to be 16.40 feet, two were to be 3.61 feet breast, the third 7.87 feet; the external diameter was to be 23.61 feet, there were to be twenty buckets of the form adopted by Rijk at Gouda, with concavity towards the outer water. The lowest point of the drum was to be at the highest internal water-level. The axis was to be at 5.90 + AP, and the extreme internal and external water-levels 1.47 − AP and 5.92 + AP respectively. The idea of the engineers was to take advantage of the experience obtained at Gouda, and to produce a perfected float-wheel. The play between the buckets and the walls was reduced to a minimum by fastening strips of wood to the edges of the former. The useful effect was prescribed as under:—

Lift.	Expansion of Steam.	No. of Revolutions per Minute.	Discharge.	Useful Effect.	Number of Wheels in Action.
Feet.			Cubic feet.	H.P.	
2.80	$\frac{6}{7}$	5.15	15.892	85	3
6.56	$\frac{4}{5}$	4 19	6.745	85	1 (the large one)

It was specified that upon the completion of the work there were to be two trials, one carried out by the drivers and stokers of the constructors, the other by those of the association under the direction of the former. The positions of the water-gauges (a frequent cause of dispute) were definitely fixed, that for the internal water at 39.4 feet from the axis of the wheels, the other at 26.25 feet. The second trial was to last for thirty days during the three months in which the constructor was to be responsible for maintenance. In the event of the consumption of coal exceeding that guaranteed by the contract, the contractor was to pay three-fourths of the capital sum which would have to be paid by the association to provide the additional coal.

There were nine tenders for the work, as under, the names being suppressed.

No. of Tender.	Price for Wheel-Pumps.	Price for Float-Wheels.	Maximum Consumption of Coal in lbs. per H.P. per Hour guaranteed.			
			Wheel-Pumps.		Float-Wheels.	
			Lift, 4.26 feet.	Lift, 6.56 feet.	Lift, 4.26 feet.	Lift, 6.56 feet.
	£.	£.				
1	4,831	4,792	6.06	6 06	6.50	6.50
2	5,290	5,290	4 84	4.84	4.84	4.84
3	5,078	5.078	4.84	4 84	4 84	4.84
4	5,375	5,375	5.50	4.95	5.50	5 50
5	6,037	6,262	6.83	6 83	6.83	6 83
6	6,230	6,490	7.40	6.45	7.40	6.45
7	6,361	6,563	6.61	6.61	6 61	6.61
8	6,138	6,338	6.61	6.61	6 61	6.61
9	8,125	8,500	5.72	5 72	5.72	5.72

The tenders were from first-rate constructors, Dutch, German, and English, and are interesting as showing their judgment upon the two systems proposed by the engineers. The prices included the whole of the machinery, with boilers, &c., complete. The contract was let to No. 1, at the rate of £57 per HP. The cost of the buildings was £7,166.

The power was transmitted through the axles of the wheels. The ventilation of these wheel-pumps was not satisfactory, though the question had been carefully considered.

The principal dimensions of the engines were: Cylinder 2.3 feet × 4 feet; capacity of the condenser, one-third that of the cylinder; diameter of fly-wheel, 16.40 feet, and its weight 7.38 tons; ratio of transmission, 7.81 to 1. The three boilers were of the Cornish type, 28 ft. 9 in. × 4 ft.

When the author visited the works they had been so short a time in operation that the consumption of coal could not be accurately ascertained, but it appeared that it would be about that of the best engines for water-lifting in Holland, namely, slightly more than 6.6 lbs. per HP. per hour. He considers that the opinion of the engineers is justified, that wheel-pumps and float-wheels are about equally good.

The engine-house is 46.50 feet long, and 18 feet broad. The boiler-house (for three boilers) is 46 feet long, and 27 5 feet broad. The chimney is 78.75 feet high above the fire-grate. Its section increases towards the top, the internal diameter being 3.60 feet at the bottom, and 4.60 feet at the top.

Zuidplas.—This deep lake owed its origin to the extraction of peat. It is not known when this extraction commenced, but there are legal regulations upon the subject as far back as the year 1595. At the beginning of the present century, windmills driving float-wheels were erected to keep down the level of the water in the lake, and in 1825 the Government determined to drain it altogether. The normal level of the water was fixed at 18.40 feet—AP. The highest level in the Yssel, into which the water had to be discharged, was 3.38 feet + AP. The total lift was, therefore, 21.78 feet, and it was decided to divide this into two distinct lifts, each of which was again subdivided into two parts.

The first principal lift was from the low-lands to a canal, which was carried round the lake at a certain level. From this canal the water was raised to a collecting basin, and thence discharged into the river by sluices. In this way the basin acted also as a regulator to the river, which is subject to great fluctuations of high and low water in times of flood. These regulating works had to be of much larger capacity in those days, when the motive-power was wind, than would now be necessary. The normal water-level in the circumscribing canal was fixed at 13.38 feet above summer level.

The lift was divided into two parts of 6.69 feet each, and the method adopted was that of Archimedean screws, driven by eleven pairs of windmills. From the canal to the river the water was raised in two lifts by means of float-wheels, the lower worked by seven, the upper by five windmills, a part of the discharge into the river being by gravitation at low tide. This arrangement was, however, modified by the introduction of two steam-engines, of 30 HP. (actual) each. These were attached to a couple of screws, which performed the whole lift of (in their case) 22.18 feet at once. The erection of these engines marks an era in the history of drainage. Although the first attempts at using steam-power were made in 1776, near Rotterdam, the only practical application had been made at Arkelschendam, and as these consumed 31 lbs. of coal per HP. per hour, it was thought that steam could not be used economically. The Zuidplas engines consumed 22 lbs. per HP. per hour, which in those days was not considered bad, and led to the adoption of steam for the Haarlem reclamation.

The thirty windmills and the two steam-engines emptied the lake in 1840, and kept it dry. They were all in action up to 1871. Each windmill, with its screw, raised the water from 2,352 acres to a height of 3.28 feet. Each wind-mill, with its float-wheel, raised that from 1,898 acres for the first half of the upper lift to a similar height, and from 2,656 for the second half. The annual cost of maintaining these thirty mills was very

high, amounting to about £1,800, or about £60 per mill.

In the meantime the cost and working expenses of steam-engines have been much reduced, while improvements in agriculture require a more perfect regulation of the water-levels, and for these reasons steam has been gradually substituted for wind-power. In 1871 ten mills were removed, and in 1873 it was decided to replace the remaining twenty by steam. A Commission of two well-known engineers was appointed, to whom the following questions were proposed:—

I. What is the best machine for raising 7,240,000 cubic feet of water per twenty-four hours, to a height varying between 11.3 feet and 12.3 feet?

II. When the height varies between 4.9 and 13.1 feet?

III. What is the best system of engines and boilers?

IV. What is the estimated expense?

The answer of the Commission to the second question was decisive: "Centrifugal pumps. No other machine applies so well to differences of level in the external and internal water. No other permits the application upon so large a scale of the whole disposable motive force to all lifts comprised within the limits stated.

"The machine adapted for the maximum lift will, with lower lifts, discharge proportionally larger volumes; while the useful effect which is produced by the coal consumed, does not vary to any great extent."

These statements of the Commission went rather too far. The duty is anything but constant,* and while it is quite true that centrifugals adapt themselves more readily to differences of lift, and are available for much higher lifts than float-wheels, they have this disadvantage, which the Commission failed to point out, namely, that there exists in each case a minimum velocity, below which they will not raise a drop of water, whereas wheels, piston-pumps, screws, &c., if working at all, always discharge water.

In reference to the first question, the Commission could not say that one form of pump was superior to all others for a high, but nearly constant lift, and they therefore recommend that as centrifugal pumps should be adopted for the second, they should also be adopted for the first case, as they consider them as good as any other form for the purpose, and by having the whole of the machinery from the same firm there would be a saving in cost.

The selection of centrifugal pumps was subject to certain conditions. They were to be direct-acting, the disks to be above the internal water-level, and the delivery-pipe was to be carried by a bend below the low-water level of the external water, so that the lift would vary with that level. Each pumping-station was to have two centrifugal pumps (Gwynne's pattern), driven by separate non-compound direct-acting engines, capable of raising 2.542 cubic feet of water each per minute. The diameter of the disk was to be not less than 6 feet, and the velocity one hundred revolutions per minute. The suction and delivery-pipes were to be at least 3 feet in diameter. The lower station was to have four, the upper three, Lancashire boilers, 25 feet × 6.5 feet, with twenty-four Galloway tubes. The maximum consumption of coal was to be 6.61 lbs. per HP. per hour, with lifts varying from 5 to 13 feet.

The recommendations of the Commission were adopted, and in 1876 the new machines were set to work.

Tables are given of the performances of the machinery, but before discussing them the author makes some observations upon the float-wheels adopted. For the lift of 11.8 feet, the diameter of wheel is 32.8 feet. which is believed to be the largest in Holland, though similar wheels, of a larger diameter, are used in Italy. Mr. Forster gives a formula for calculating the diameter as follows: Given i, the immersion of the paddles, p the lift, then the diameter $D = 9.82\sqrt{i+p} = 9.82\sqrt{H}$, in which H = the height from the lowest point of the wheel to the highest external level to which the water has to be raised, the measurements being in feet.

The Dutch use smaller diameters, part-

* Mr. Backer, one of the commissioners, has since expressed another opinion founded upon his later experience ("Rapport over den Waterstaatstoestand"), that the consumption of good coal per HP. per hour for centrifugal pumps when working at their full power varies with the lift, and is, for lifts of 7.2 feet, 6.6 lbs.; for lifts of 1 foot, 2.4 feet; and from 3.3 feet to 5.3 feet, 9.37 lbs., 8.82 lbs., and 7.71 lbs. respectively, not counting the coal required for getting up steam, which he puts at 4 per cent. in his own case, but which varies with the number of interruptions to the work.

ly on account of the great weight of their wheels, partly from being accustomed to wind-power, for which they are more suitable. At Katwijk, where the wheels of most recent construction have a lift varying from 12.14 feet to 13.17 feet, the diameter is only 31.17 feet, while, according to the Italian custom, the diameter of the lowest lift should be 39.6 feet. At Zuidplas, $i = 3.28$ feet, $p = 11.8$. D should therefore, by the Italian rule, be 38 feet. It is only 32.8 feet. It should be observed, however, that the Katwijk wheels are similar to those used in Italy, but those at Zuidplas have curved paddles, on Korevaar's system, and for this reason the diameter is less than it otherwise would be, as also is the immersion. For this type the inventor gives D=2 H as the minimum diameter.

The author has several times seen the Zuidplas wheels at work. When the levels are favorable the wheel enters the water well, meeting it with the edge of the float; but the lower wheel, which has a high lift, does not leave the water as it should, but throws it to an unnecessary height. The upper wheel, however, with a lift of 8.20 feet, acts better. For the lower, the diameter of 32.8 feet is too little for the lift of 11.8 feet, notwithstanding the curvature of the paddles. This curvature, which is concave towards the internal water, has a disadvantage attending it, that when the level of the internal water lowers to such a depth that the convex surface, instead of the edge of the paddle, strikes the water, it drives the water backwards to a certain extent, instead of carrying it forwards.

The author now refers to the actual results of the working of the various machines at Zuidplas. There is this notable feature about the works, that there are two pairs of pumping-stations, with machines of two different types, while those of one pair are identical in construction, and work under different conditions as to lift. The volume of water discharged may be taken as constant for each pair. The Tables show that neither with paddle-wheels nor with centrifugal pumps is the consumption of coal proportional to the lift, or to the work done. In the case of the wheels, the contract specified that the actual H.P. should be 90 each, and the total consumption of coal (Ruhr of the first quality) should not exceed 595 lbs. per hour with any ordinary lift, with a penalty or premium of £1 13*s.* for each 2.2 lbs. over or under 595. It is hardly necessary to observe that the trial proved satisfactory and obtained a premium. In practice, however, the upper wheel especially was far from satisfying these conditions. The lower wheel, though apparently working under much less favorable conditions than the upper, gives a considerably better effect, owing to the fact that with these wheels the effect increases rapidly with the lift. The weight of each wheel, with its axle, is not less than 21 tons. The velocity of periphery is about 6.5 feet per second. The actual discharge of these wheels is 92 per cent. of the theoretical. It amounts to 3960 cubic feet per minute for each wheel, and the lift being 11 feet 9 inches, the actual H.P. is 89. The consumption of coal in ordinary working is 7 lbs. per H.P. per hour.

It should be observed that while the wheels very frequently worked day and night, the centrifugal worked generally at intervals, and sometimes for very short periods, as, whenever the state of the tide permitted, the water was simply discharged by gravity through sluices, but the boilers were nevertheless kept in steam, and the consumption of coal reduced to pounds per HP. per hour, is no doubt greater than it would have been had the pumps been working continuously. The tables given in the Paper show that the duty of the wheels was somewhat better than that of the pumps, but no doubt this is partly accounted for by the above circumstance. In these pumps the power measured by the water raised varies from 40 to 49.7 per cent. of the indicated HP., and the consumption of coal is 7.67 lbs. per actual HP. per hour.

In one respect, however, the wheels are decidedly more economical, namely, the consumption of lubricants. An inspection of the books for 1877 shows that the consumption per HP. per hour was—

	Pint.
For the wheels	0.0053
" centrifugals	0.0123

The principal dimensions of the buildings are.

For the float-wheels—

	Ft.
Outside length of engine and boiler-house	69
" width of engine-house	37
" " boiler-house	40

For the centrifugals—

	Feet.
Internal dimensions of room for two pumps	33 × 28
Internal dimensions of boiler-house	36 × 42
Coal store (not roofed)	98 × 66
Engine driver's house	33 × 27

The two steam-engines, with the two wheels of 32.8 feet diameter, and another, not working, of 16.4 feet diameter, cost £5,000, or per HP. £28.

The four centrifugals, with engines and boilers, cost £11,833, or per HP £46.

The cost of the buildings is not given. Mr. Korevaar says that the cost in pounds of float-wheels, including all machinery and buildings complete is $666 + 66\,k$, in which k is the horse-power. This rule applies to all powers between 6 and 100.

Bullewijker-polder.—At this polder very careful experiments have been made by the engineer, Mr. Elink Sterk, upon the performances of the centrifugal pumps supplied by Messrs. J. and H. Gwynne, of which the following are the dimensions:—

	Ft.	In.
Diameter of steam-cylinder	1	8
Stroke	1	6
Diameter of the disk of the centrifugal pump	5	7
Width of blades at the periphery	0	5½
Angle of the blades at the periphery	17°	
" " " axis	90°	
Diameter of the suction and delivery pipes	2	6
Cost of engine, pump and one boiler (heating-surface 743 square feet)	£. 2,154	
Cost of reserve boiler	472	
Total cost	2,626	

This is exclusive of erection, and of suction and delivery pipes.

OBSERVATIONS ON THE CONSUMPTION OF COAL.

Lift from	14.3 feet to 15.3 ft.
Discharge per second, maximum	41.8 cu. ft. per second.
Discharge per second, minimum	32.5 cu. ft. per second.
Discharge per second, mean	36.0 cu. ft. per second.
Mean effective H.P.	62.219 " "
Consumption of Westphalian coal during the experiments, which lasted 6 2/3 hrs.	1,938 lbs., or 5.22 lbs. per H.P. per hour.
Number of revolutions, from	134.4 to 136.5
Pressure in boiler, from	66 to 76 lbs.

EXPERIMENTS WITH THE INDICATOR.

Pressure in boiler	71 lbs.
Introduction, from	10 to 14 per cent.
Vacuum in condenser	25½ inches.
Revolutions per minute	135.8
Indicated H.P.	117.7
Discharge per second, from	40.26 cu. ft. to 40.64 cu. ft.
Lift	14.5 feet.
Effective H.P.	68.57 to 69.07
Ratio of effective to indicated H.P.	from 0.583 to 0.587

In these experiments the water was measured very accurately. The results are the more satisfactory because the suction and delivery pipes were unusually long, 49 and 85 feet respectively. These pipes are not of constant diameter, but diminish as they approach the pumps.

It appears that in Italy centrifugal pumps have been discredited, owing to unsatisfactory results obtained from a set erected at Codigoro in 1874 by Messrs. J. and H. Gwynne, and the author is desirous of pointing out the great improvements effected since that date.

North Sea Canal.—In order to regulate the level of this canal, which receives the waters of very extensive boezems, and of the polders formed upon the bed of the Y, the company have been obliged to erect several pumping-stations, of which the principal is that of Schellingwoude, near Amsterdam. A peculiarity of these pumping-stations is the application of Appold's turbine pumps, which the author describes.

The results were by no means satisfactory, the consumption of coal being not less than 11 lbs., but it is to be noted that the actual quantity of water raised was in excess of that for which the engines were designed, and it was upon this latter that the calculations were made; also that the lift was less than was expected, which would partly account for the excessive consumption. These turbines, in consequence of these results, are now never used.

Turbine pumps on a very small scale are used for draining small areas of about 75 acres, with lifts of less than 1 foot 6 inches. They are made of wood, and driven by wind power. They occupy a space of 4 feet by 4 feet, and cost between £16 and £25.

Except in this diminutive scale turbine pumps are not now in request in Holland.

In Italy on the other hand they are said to answer well.

City of Rotterdam.—Rotterdam has three pumping-stations with machinery of an entirely different character to any of those previously described. Their use is to regulate the water-level in the suburban part of the town called Polderstad. They discharge water into the Meuse, and also introduce fresh water from the river into the canals. The canals are greatly polluted by sewage matter.

There are three pumping-stations, two of which are provided with lift and force pumps, the third with a Fijnje's pump,* which is driven by an engine with a cylinder 2.75 feet×6.89, the size of the pump being 6 feet×4.92 feet. The cost of the whole machinery was £4,166, or £104 per HP.

A table is given, showing the performance and duty of this and the other two pumps at Rotterdam.

Fijnje's pumps are very simple, but have the disadvantage of requiring deep foundations.

Haarlem Lake.—A description of Dutch pumping machinery would be incomplete if no mention were made of the three pumping-stations which have dried up and keep drained the former lake of Haarlem, covering an area of 44,480 acres. The emptying of the lake was begun in 1849 and finished in 1852. A table prepared by the engineers, Mr. Van de Poll and Mr. Elink Sterk, is given, showing the performance of the engines at the three stations, Cruqius, Lijnden, and Leeghwater. The dimensions of these machines are:—At Leeghwater, engine cylinders, small, 7 feet, large, 12 feet diameter, stroke 9.3 feet; pumps, 11 in number, diameter 5.25 feet, stroke 9.3 feet. At Cruqius and Lijnden, the diameters of the cylinders as above, stroke, 8.86 feet; pumps, 11 in number, diameter, 6 feet, stroke, 8.86 feet Ratio of the effective to the calculated discharge (at the normal velocity), for Leeghwater about 84 per cent. (this is somewhat doubtful), for Cruqius 89 per cent. (this figure is reliable). The consumption of coal as found by records extending over a considerable time is 6.83 lbs. per HP. per hour.

Mr. Sterk made some experiments with a view to ascertain the difference in working at the normal speed of about 7 strokes per minute, and when this was reduced to 3 strokes. With seven pumps at work, he found that in the latter case the indicated HP. was 192, the effective 134 HP., or 0.698 of that indicated. The consumption of coal was 5.44 lbs. per indicated, and 7.80 lbs. per effective HP. per hour. When working 7 strokes per minute, the indicated HP. was 492, the effective 361, the consumption of coal 4.94 lbs. per indicated, and 6.74 lbs. per effective, HP. per hour.

The coefficient of useful effect of the pumps is higher than that of any other machines in Holland; that of the motors on the other hand is small, and the consumption of coal per indicated HP. per hour is more than double that of good modern engines.

Comparative Notes upon the Various Systems.—Besides those described, various other hydraulic machines are in use in Holland, notably a species of Archimedean screw, which is very simple in construction and easily erected. It is well adapted for working by wind-power, and is a most useful machine for lifts which are too high for wheels. It requires, however, that the level of the external water should be nearly constant.

From analytical investigation, and from experiments carried out under certain conditions, it would appear that the best hydraulic machines are piston-pumps, and the worst centrifugals. Notwithstanding this fact, however, it is certain that in Holland, where pumping-machinery is used to such a very large extent, centrifugal pumps are preferred, and piston-pumps are the least used. In all pumping-machinery the duty varies greatly with the lift; this is recognized by the makers of centrifugals, so that in recent contracts at least three conditions of lift are specified, and for each the consumption of coal per HP. per hour is fixed. In the opinion of one of the principal Dutch authorities, the mechanical effect differs much less than is imagined between different classes of machines, and in designing a new establishment the greatest importance should be attached to other circumstances; such as the turbidity of

* These pumps were first used in Holland in 1847. They have since been introduced into Germany, and lately into America, where, owing to their success at the Philadelphia Exhibition, they have been applied on a large scale at several places.

the water, the probability of the internal water-level being permanently lowered in time, the nature of the foundations, the method of establishing communication between the inner and outer water, the level at which the machine can be placed with reference to the water to be discharged, upon which depends to a greater or less extent the facility of superintending and repairing the machinery, the security against inundations, the frequency of frost, &c.; also the cost of erection and working.

When flood-water conveying a large amount of *débris* has to be raised, piston-pumps are unsuitable, as they are liable to be damaged, and to have their valves choked. Centrifugals are better in such cases, but wheels are the best, and they have the further advantage that they can be easily repaired by ordinary workmen. The motors may be of common types, the only difficulty being that of adapting them to low velocities. With a diameter of 30 feet for instance the wheel must not make more than four and a half revolutions per minute, and with a single system of gearing the speed of the engines would have to be limited, for, with an ordinary speed of 70 strokes per minute, the ratio of transmission would be $\frac{1}{15.5}$ which is too high. On the other hand the tendency is to construct engines to work at high speeds, as being more economical.

Again, the system of direct action between engine and pump is the one which is most economical in fuel, but here the difficulty is that too high a velocity is required; for instance, at Legmeer, the engine makes 168 strokes per minute.

In regard to foundations, wheels are at a disadvantage compared to centrifugals, for, with a high lift the wheel must have a large diameter, the sill must have a low level, and this necessitates massive and deep masonry. In some cases this question of foundations is a very important one, and would determine the kind of machinery employed.

Another important point is the liability of the internal water to have its level permanently lowered. With machines in which the water is conducted to the pump by pipes, additional lengths can always be added to the piping, and the only difference is that the consumption of steam will be greater, but with wheels, screws, and possibly with force-pumps, a lowering of the level of the water would require costly alterations.

It is well known that such alterations of level occur in draining marsh-lands, and their amount varies with the nature of the soil; their extent is small in the case of sand, larger in clay, and greatest in muddy ground.

In regard to the separation between internal and external waters, the easiest and safest arrangement is that of pumps which discharge the water through pipes which are inserted in masonry walls of sufficient thickness. With wheels and screws much larger apertures are required, and these must be protected by strong sluices.

The Dutch hydraulic authorities state as general principles that for lifts above 16 feet 6 inches, wheels cannot be used, as their diameter would be too great. When the level of the external water is subject to great fluctuations screws cannot be used, as the amount of fluctuation allowable depends upon the radius of the screw, which cannot be more than 4 feet. When the water is very turbid, valve pumps are inadmissible; for moderate lifts, particularly when pretty constant, they recommend float-wheels, if for no other reason, on account of their simplicity and well-known durability.

It may be stated in general, that the useful effect of every machine varies greatly with the lift, and that in estimating the consumption of fuel, it is not enough to take the mean ordinary lift, but the variations must be studied and grouped together, the consumption due to each lift per HP. per hour must be computed from the results of existing machines.

The following table shows the number of pumping machines of different types erected in Holland in the years 1875 to 1881:—

(See table on page 295.)

* The author concludes from the result of his investigations that no general rule can be given as the employment of one or other of the different machines, but that all the circumstances of each case must be considered before a decision is come to as to what machine to use.

	1875.	1876.	1877.	1878.	1879.	1880.	1881.	Totals
Float-wheels	3	1	1	4	12	9	8	38
Centrifugal pumps	1	1	6	6	11	9	16	50
Float-wheels and centrifugal pumps, combined	—	—	—	1	—	1	1	3
Wheel-pumps	—	—	—	1	—	1	—	2
Screws	3	1	7	2	12	4	1	30
Piston-pumps	—	—	1	1	—	—	2	4
Various	3	—	2	6	—	1	—	12
Totals for each year	10	3	17	21	35	25	28	139

APPENDIX.

While the proofs of the last sheets were being revised by the author, he received a copy of the "Tijdschrift" of the Dutch Institution of Engineers, containing a paper by Mr. Korevaar, entitled, "What are the most suitable machines for keeping polders drained?"

Though Mr. Korevaar does not in all cases agree with the author's conclusions, the latter sees no sufficient reason for changing his opinions.

Mr. Korevaar begins by saying that the only machines which deserve discussion are float-wheels, wheel-pumps, suction-pumps, lift and force-pumps, and centrifugals. He considers that all are effective when rightly proportioned, and that the first outlay does not differ much between them. The real point to be considered is the expense of working, and he endeavors to ascertain what are the most economical in this respect. But first he gives certain rules as to the discharge and lift suitable to each class of machines.

Float-wheels are capable of discharging 8800 cubic feet per minute, and have the advantage that they can be worked at any lift up to the maximum for which they are designed without any useless raising of the water. They will work up to a lift of 12.3 feet, the ordinary limit being 9.84 feet. For screws he states that if the external water-level descends more than about 1 foot 6 inches below the maximum there will be a wasteful lifting effect. Limits of lift and discharge are 14 feet and 3,500 cubic feet per minute. For suction pumps he gives 2,120 cubic feet and 16 feet 6 inches; for double-acting lift and force pumps in pairs a discharge of 5,300 cubic feet per pair, and 40 feet or more lift. He estimates the maximum discharge of centrifugals at 3,500 cubic feet, and lift 40 feet.

Mr. Korevaar gives the following as the ratios between useful effect and indicated power in the cylinders:—

Float-wheels	0.67
Lift and force-pumps	0.70
Centrifugal pumps	0.45

He also describes investigations carried on at fourteen pumping stations from September 1880 to May 1882 into the consumption of coal by the different classes of machines, the results of which he gives thus in hectoliters of coal consumed per hectare and per meter of lift:—

	Hectoliter.
Float-wheels	1.06
Lift and force pumps	1.06
Similar pumps combined with float-wheels	1.04
Centrifugal pumps	1.77

Whence he concludes that centrifugals consume at least 50 per cent. more coal than the other machines.

The author does not agree with Mr. Korevaar, whose condemnation of centrifugals he considers to be based upon somewhat unfair treatment, those experimented upon being of old-fashioned types, and working under unfavorable conditions. He also, however, considers that centrifugals consume more coal than any other class of pumping machine, and that suction-pumps consume less. He insists again, however, on the necessity of a careful examination of all the features of each particular case previous to deciding what machine to adopt.

THE CONSTRUCTION OF CHIMNEYS.*

By JOHN P. SEDDON.

From "The Architect."

CHIMNEYS, at present at any rate, are integral and important features of ordinary buildings in England. It may be that they can and will ultimately be altogether dispensed with, and our towns made, by the progress of economic science, to resemble those in the East—mere collections of flat-roofed boxes; and these may possibly be fed with fresh air of varied temperature, and drained of their fouled air by some parish pump and common heating apparatus. When this scientific millennium arrives, such dwellings may be left to purely scientific men, to whom æsthetic considerations are questions of superfluity.

I have, however, now to speak as an architect, addressing a sanitary conference, upon chimneys as existent, and I wish to show how they can and should be treated, that they may be practically useful and ornamental as well. They have been both in former times; witness the graceful chimney-shafts of Grosmont Castle, Southwell Priory, Hampton Court, and a host of Elizabethan mansions, the acknowledged picturesqueness of which is mainly due to the treatment of their chimney-stacks. Alas! however, they are seldom either useful or ornamental now-a-days, as a glance at the skylines of our streets will reveal, since they are almost invariably disfigured by ugly cowls and "tallboys." These are but records of domestic misery and discomfort, every one representing a martyrdom, endured until it became intolerable; and their aggregate cost amounts to a tax upon the inhabitants of our cities which, were it an enforced one, might lead to a revolution. Yet the makers of such monstrosities occupy no inconsiderable space in this very Health Exhibition, and recommend their wares as palliatives for a disease which they assume to be not only universal but inevitable. I maintain that it is not the latter, and need not be the former, and that such costly and ugly excrescences may be altogether dispensed with, if but a little attention be given to the proper construction of these portions of our buildings—chimneys and fireplaces.

Now, let me ask, why do our chimneys smoke? Firstly, because, as a rule, air is not laid on or provided to houses as water is; but rather, indeed, it is in general sedulously excluded. The more sanitarily impervious (that is to say, air-tight) we make our dwellings, the more necessary it is to provide for the admission of fresh air to their interiors, and, unless this be done, smoke cannot ascend the flues of their chimneys; secondly, chimneys smoke because the fireplaces are ill-constructed, and gathered over from the openings of the fireplaces to the flues in such a gradual manner as to leave large vacant spaces above the grates, which act as reservoirs for stagnant cold air, by contact with which the smoke is chilled and prevented from rising and being drawn at once into the flues; thirdly chimneys smoke because flues are ordinarily made too large (the usual size is 14 inches by 9 inches); they should rarely be made more than 9 inches by 9 inches; fourthly, because no provision is made in the flues for such down draughts of air as may invade them to expend and exhaust themselves before they reach the fire-place; and fifthly, because the tops of the chimney-shafts are not carefully constructed with guards against wind in a proper and sightly—that is to say, an architectural manner. Usually all such provision is left to be supplemented by some miserable metal makeshifts, by the chimney-quacks whose fantastic creations Dickens satirized so keenly, and yet, as it would appear even from this exhibition, quite vainly.

As it is useless to expect that chimneys can properly perform their office, of conducting readily into the outer atmosphere the smoke from fireplaces, unless their construction is proper throughout, I shall treat of the fireplace, flue and chimney-top as a whole, of which the several parts are inseparably connected; and I shall begin at the bottom with the fireplace, as the most important of the

* A paper read at the Conference of Architects at the International Health Exhibition.

three, and the one most commonly in fault in the case of smoking chimneys, although it is generally the last to be noticed or examined with a view to its correction. The grate itself, however, I shall leave for later consideration, though it is by no means of the least importance.

The first thing to be done is to provide a good and sufficient supply of fresh air to the fireplace from the outside of the building. To insure its being good it is well, when possible, to bring this from as high a level as can be arranged, yet not from the top of the chimney-stack, lest smoke from other flues be drawn down thence with the fresh air. It may be drawn from the lower part of the stack, just above the roof, by special air flues brought down the chimney jambs. This, however, is not always possible, and then it must be brought in through the walls or by pipes through the floors. An advantage of bringing the fresh air to the fireplace, rather than to any other part of an apartment, is that even if cold, it does not produce the inconvenient draughts usually complained of. It spreads thence upwards and gradually, before being finally drawn up the chimney by the fire in the fireplace; whereas, if admitted elsewhere, its passage is direct to the fire, and unpleasantly so to those who may intercept its course. When no provision for air is made, it has to force its way in at windows and doors, with the same result, made all the worse because of the low temperature at which it enters. The air, however, brought to this point, may be tempered or warmed by being made to pass around the grate before it is admitted to the apartment, and an essential for both comfort and health is that it should be so tempered; every grate, stove, or heating apparatus should, in fact, be thus made the fountain or source whence fresh air is admitted to apartments.

The next point to be considered is that of the outlet of the smoke from the fireplace to the flue. The flue should be here contracted at once to its normal size, or rather made a little smaller, immediately above the fireplace, in order to promote a quick draft of the smoke into it. The usual construction of this part of chimneys, already adverted to, does not conduce to this end. The opening of the fireplace is gathered gradually, in an arched form, to the flue, leaving an objectionable space for cold air. Now, arch and chimney-bar may be economically dispensed with by forming a mantle block in Portland cement concrete *in situ*, extending the full width of the wall, and 9 inches longer than the opening, and 9 or 12 inches deep, pierced with the smoke flue in the center, and one for warmed air on either side. These may be circular, and about 8 inches in diameter, and thus being slightly smaller than the flue over, will insure a quick draft to the smoke flue. The side holes are intended as outlets for the fresh air that has passed round the grates, and thus can be conducted by flues built above the mantle block to gratings for admitting it into the apartment, either in connection with the chimneypiece, or just below the ceiling.

The construction of the smoke flue from above the central hole in the mantle block is the next point deserving and requiring consideration. As has been said, this is ordinarily made 14 inches by 9 inches, but this is too large, and as such becomes a frequent cause for smoking chimneys. Flues should not generally be made more than 9 inches by 9 inches in brickwork, and are better if lined with fireclay pipes within such, which reduces them to about 8 inches in clear circular diameter. The interior surfaces of the pipes should not be smooth, or else much inconvenience will be caused by frequent small falls of soot, from its being unable to cling to the pipes at all.

Midway between the top of the mantle block and the ceiling line of the apartment, the smoke-flue should have a portion expanded and formed in such a manner as to break the direct line of ascent of the smoke. This is in order to allow down draughts or gusts of air that have invaded the flues from the top to expend themselves, without checking the smoke as it rises from the fireplace. A flat ledge should be provided in this expanded part of the flue, immediately under the smoke-flue above, that air driven down may impinge upon it, and be diverted, and a sideways rotary motion given to it, directing it upwards again, together with the smoke rising from below. Specially-formed pipes can

be introduced into flues lined with fireclay pipes for this purpose, and more than one of these may be inserted in the course of the flues with advantage.

We now have arrived at the chimney-stack above the roofs, and the principal object in its construction is to maintain throughout its warmth, as it is there of course exposed to cold and damp; and it is well known and observed that those chimneys which are in external walls are, from this cause, far more liable than others to smoke. Pervious brickwork becomes saturated by rain, and the flues consequently reduced in temperature are unable to maintain the requisite upward draught. It is well, therefore, for this reason as well as for additional strength, that the chimney-stacks above the roof should be built in cement instead of common mortar, and of impervious bricks or stone and lined with fireclay pipes.

The tops of the chimney-stacks need careful arrangement, because the exit of the smoke from them is very liable to be disturbed and hindered by gusts of wind, particularly when beneath other high objects in the neighborhood. There should, therefore, be at the top of every flue an expanded space, within which most down draughts of air will rotate and expend their force without invading the flue below; and there should be louvred openings so arranged as to direct the wind upwards, and so make it to assist, instead of interfering with or retarding, the exit of smoke. This is the object generally and often rightly attempted by the supplementary cowls, at any rate by the best of them, but it may and should be rather executed in proper architectural form, and durable and sightly materials, such as stone, brickwork or terra-cotta, instead of metal. Terra-cotta is perhaps specially suitable, as being very easily manipulated into the somewhat complicated forms required for the purpose.

So much, then, for the construction of these three parts of a chimney, the fireplace, the flue, and the chimney terminal of the stack. Unless all are well and properly executed, no special appliances for particular parts can be of much avail. I have endeavored to point out the general principles that I think should be attended to in connection with them, and believing that the health and comfort of the community is at present very injuriously affected by their general neglect, I earnestly commend them to the consideration of this Conference.

There is, however, one more part connected with the chimney, which is perhaps quite as important as any of the rest with which I have dealt, but what I have to say about it is somewhat more tentative and experimental. This is the grate within the fireplace. Volumes have been written about it, and yet it remains open for discussion and inviting improvement. My contribution to its literature will be short, and yet it will embody the result of much time and thought expended upon it.

Burning coal principally, as we do in England, we have to seek in the consumption of its smoke, or at least of as large a proportion of it as possible, within the grate itself, the solution of the main difficulties we are considering. For the smoke being consumed, smoky chimneys will be cured. The office of the flue will then be to convey away the gaseous products of combustion only, and not soot. This is, I believe, attainable by means of diverting the current of the smoke, after it has issued from the top of the fire, in such a manner as to force it to pass through the body of the fire before it ultimately is allowed to escape up the chimney flue. Perfect combustion is, I think, more to be sought than what is called "slow combustion," and it is a mistake in my opinion to smother a fire in its own ashes, by preventing their dripping through a grating into an ashpan. The cheerful aspect of an English open fire is not likely to be driven out of fashion by even Health Exhibitions; nor if it could be, and the attempt were made, do I think that the public salubrity would be improved by the substitution of any description of close stoves in apartments, notwithstanding the preference they have obtained on the Continent, and to a great extent in America. Nor do I believe that any of the systems that have been proposed for keeping up throughout dwellings an equable temperature, are likely long to curtail the liberty of English subjects to make their several rooms of whatever degree of heat it may please their occupants. I should certainly, therefore, not advise the most ardent believer in such a system to expend capital in build-

ing houses otherwise than at present, or to try to dispense with chimneys, the construction of which I have been dealing with.

But there are many grates shown in this exhibition which presume fresh air to be brought to them, and in which means are provided for warming and distributing such air into apartments, and I cannot too highly commend the system, and advise its universal adoption by the public; and I may point out that this can and should be done, more often than it is, in the case of the kitchen chimney, which is almost always in use, and that the air warmed thereby not being wanted in the kitchen, should be conducted to the general hall of the house, which supplies air to the rooms whenever their doors are opened, though of course there should be means of shutting it off in summer, when it might prove rather a nuisance than otherwise.

Trusting then that soon, if it be not already achieved by any of the grates shown in this exhibition, that most desirable end, the consumption of smoke within the grate itself will be successfully carried out, I conclude these few observations upon the construction of chimneys, waiting discussion thereon from the members of this Conference.

VENTILATION IN CONNECTION WITH WARMTH AND LIGHTING.*

By Captain DOUGLAS GALTON, C.B., LL.D., F.R.S.A.

From "The Building News."

In this lecture I propose to endeavor to explain what are the principles which should guide us in warming our houses, and then to endeavor to show how those principles can be usefully employed in practice. We must all agree that our present arrangements are inconvenient in certain respects, so far as our towns are concerned. When we bring a large number of houses together, as we do in our great cities, the methods which we adopt for warming our houses conduce to the production of a very large amount of smoke and pollution of the atmosphere. The amount of coal which we burn is out of all proportion to the heat which we produce. Therefore, in our towns, the methods to which we resort for warming our rooms load with impurities the air which we have to breathe. Those who have been born and have lived in the heart of London, do not know what the feeling is of breathing fresh invigorating country air. The question is: How can we alter this? The first step toward alteration is to know what conditions we want to obtain. We will consider, in the first place, what advantages our present methods of warming secure for us; and next, how we can secure these in ways less hurtful to our atmosphere. The open fire is the most favorite method of warming. So far as the production of heat is concerned, it is also the most wasteful. One pound of coal is more than sufficient, if all the heat of combustion is utilized, to raise the temperature of a room 20 ft. square and 12 ft. high, to 10° above the temperature of the outer air. If the room were not ventilated at all, and the walls were composed of non-conducting materials, the consumption of fuel to maintain this temperature would be very small; but we must change the air of the room if we are to live in it, or else the act of breathing would render the air so impure that we should die. The air which passes out of the room to make way for fresh air is warm, and carries some heat with it; the fresh air which comes in, if cold, absorbs heat, which brings up its temperature to that of the room. All this entails a development of additional heat. For instance, if the volume of air contained in the room above mentioned were changed every hour, one pound of coal additional would be required per hour to heat the inflowing air, so that to maintain the temperature at 10° above that of the outer air during 12 hours would require 12 lbs. of coal. Besides this, there is a continual

* A paper read at the Health Exhibition, July 18, 1884.

escape of heat going on through the walls, windows, ceiling, etc., and thus the mere circumstances of occupation of a room entail a greater consumption of fuel than the mere 1 lb. of coal in order to maintain the temperature. But the open fire consumes much more than would be necessary to keep up the heat. The principle of the ordinary open fire-place is that the coal shall be placed in a grate, to which air is admitted from the bottom and sides to aid in the combustion of the coal; and an ordinary fire-place, for a room of 20 ft. square and 12 ft. high, will contain from about 15 lbs. to 20 lbs. at a time, and, if the fire be kept up for 12 hours, probably the consumption will be about 100 lbs., or the consumption may be assumed at about 8 lbs. of coal an hour. But the consumption of fuel enables the open fire to perform other functions besides those of warming. It is a great engine of ventilation. One pound of coal may be assumed to require, for its perfect combustion, 160 cubic feet of atmospheric air; 8 lbs. would require 1,280 cubic feet; but at a very low computation of the velocity of the gases in an ordinary chimney-flue the air would pass up the chimney at a rate of from 4 ft. to 6 ft. per second, or from 14,000 to 20,000 cubic feet per hour; with the chimneys in ordinary use, a velocity of from 10 ft. to 15 feet per second often prevails, giving an outflow of air of from 35,000 to 40,000 cubic feet per hour. We have, therefore, to consider the open fire in two aspects: —1. As a method of warming. 2. As an engine of ventilation. In its aspect of warming, the radiant heat from the fire does not warm the air of the room; the rays from the fire warm the sides and back and parts adjacent to the grate, they warm the walls, floor, ceiling, and the furniture of the room, and these impart heat to the air. The form and material of the fire-place can thus assist materially the warming of the air. The rays should impinge more freely on the walls and floor than on the ceiling. A projecting chimney-piece with a surface favorable to the absorption and emission of heat would be more favorable to the warming and circulation of the air than one which would allow the rays to pass to the ceiling. In an ordinary fire-place the sides should be splayed, as in the Rumford form of grate; the sides and back should be of non-conducting material, with a surface favorable to the rapid absorption and emission of heat. Thus brick or tiles are better than iron for this purpose. Similarly, the degree to which the materials of the walls or floor of the room are unfavorable to conduction, but favorable to the absorption and emission of heat, will have a bearing on the capacity of the room for warmth. The open fire, moreover, has this advantage: that a person can obtain just as much or as little heat as he desires by placing himself in front of the fire or at the side. There is, however, this inconvenience about the open fire. The large volume of air drawn out of a room by the chimney must be supplied from somewhere, and consequently the very means adopted to heat the room tends to produce draughts, because the stronger the direct radiation, or rather the brighter the flame, in open fire-places, the stronger must be the draught of the fire and the abstraction of heat. Let us next consider what are the conditions which we require for comfort. The normal temperature of the human body is 98° Fahr. If it rises much above or falls much below that, death will ensue. But the human body is a furnace in which the process of combustion is continually going on. Therefore, in order to preserve the normal temperature, the body must continually give off a certain amount of heat. By the laws of radiation, a heated body parts with its heat more or less rapidly in proportion to the low or high temperature of bodies near it. Thus, if a hot body be placed near a cold body, the hot body will radiate heat rapidly. If the hot body be near a body less hot than itself, but still hot, it will part with its temperature slowly. Let us apply this to a room. If you are sitting in a room near a cold brick wall, you feel what you think is a draught. It is not necessarily a draught at all. But the side of your warm body turned next the wall parts with its heat rapidly, and you experience a local chill. If you hang a piece of carpet against the wall, the draught is no longer felt, because the carpet checks the rapidity of the radiation. Now, the chief source of heat in the open fire is its radiant heat, and as it warms the walls of the room and the furniture, it takes off any sensation of chill from the walls, &c., although the air may be comparatively

cool. You must next bear in mind that the proportion of radiant heat to the total heat given out by a heated body, depends on the temperature of the body. Thus, with a red-hot piece of iron, or a flame, the great part of the heat given out is radiant heat; whereas, with a body heated to from 150° to 200°, like a hot-water pipe, a comparatively small proportion is radiant heat. Therefore, when you heat a room by means of hot-water pipes, or by means of warmed air, the walls do not get warmed in the same proportion, and although the air may feel warm, the walls may remain cold, so that the heat of the body may be radiated to the walls and give the sensation of chill. I confess that personally I think there is nothing to compare with what my friend, Sir F. Bramwell, calls the pleasant, pokeable fire. But I do feel most strongly that, however much private feelings may incline us all to use the open fire, it is our duty, now that our towns are becoming so vast, to adopt some method of heating which will produce less smoke. It is not as if there was any probable and early limit to the size of London or of other large towns. They grow continuously, and London has progressed at the same steady rate since the beginning of this century. In 1851 it contained a little over 2,000,000 inhabitants, and was looked upon as vast and abnormal. It now contains 4,000,000, and is steadily increasing. The smoke destroys our light, it injures our air, it ruins our furniture, our pictures, our decorations, and with the increase of London, this must go on in an accelerating ratio. But it requires education in the people to get rid of it. The Smoke Abatement Society sounded the first note against this gigantic evil. In response to the demand then made, many new forms of fire-place were proposed; but the practical conclusion to be derived from that exhibition, was that so long as we burn our fuel in the raw state in our rooms and in our kitchens, we cannot get rid of smoke. The main object of the present exhibition is to educate the people in the science of health. The public has long felt the want of pure water, and has obtained a supply of comparatively pure water in the metropolis. The public has not yet become fully alive to the necessity of pure air. It is our business at this exhibition to endeavor to awaken the public mind to this want. So far as purity of air depends on removal of refuse from our midst, there is hope that in that respect this object may be attained, although no doubt even this simple question is much neglected. Dust is generally removed in open baskets, and emptied into open carts, in a manner which seems to have been designed for the purpose of scattering it as much as possible into the surrounding atmosphere. But the purity of air which depends upon the absence of smoke is another matter, and I fear that it will be many years before the selfishness of the community will give way on this point. The first point to consider is, if we dispense with the use of the open fire, how can we obtain that comfort which the open fire-place gives. The comfort of the open fire is due to the warmth it imparts to the floor, the walls, and the furniture. The air of the room is warmed, not by the rays from the fire, but by the warmth imparted by those rays to those various objects. Therefore the air of the room is somewhat cooler than the walls. Now there is undoubtedly greater exhilaration produced by breathing cool air than by breathing warm air. This is readily accounted for. One cubic foot of cold air contains more oxygen, because it is condensed, than the same volume of expanded warmer air. It is thus desirable that air admitted to a room should not exceed from 55° to 60° temperature, for comfort in breathing. This will at once explain to you why the employment of warmed air alone to warm your houses does not give comfort. If the warmed air is admitted at a comfortable temperature for breathing—viz., about 55°, the walls, which derive their heat from the air, will be somewhat below that temperature. The discomfort is caused by the warm body radiating its heat too rapidly to the colder walls. Therefore, if you are to abandon the open fire, but retain its comfort, you must warm the walls and floors, &c., of your rooms. If you can maintain your walls, floors, and ceilings, at a temperature of from 55° to 65°, combined with an adequate change of air, you will not experience much inconvenience from the loss of the open fire, however much you may regret its companionship and its pokeableness, There are four ways in which

we may effect this. In three of these ways one fire in each house in a central position would be used. In the fourth the heat would be applied in the room itself by means of gas. It is probable, however, that a combined arrangement would be desirable. In all the cases where the heat is furnished from one fire, this fire would be in a close furnace for warming each house, or self-contained block of buildings; and thus the fire could be so arranged by means of self-feeding apparatus as to be practically smokeless. The heat from the fire would be conveyed to the various parts of the building by hot air, hot water, or steam. Where warmed air is used, it would be necessary to adapt the house in its original construction to the purpose, because the air would have to flow up, through spaces in the walls, from the basement. Moreover, it would not be economical to bring up the air in the outside walls, because then nearly half the heat would pass direct to the outer air. The warmed air passing up the central walls of the house would part with some of its heat to the walls, and would thus enter the room at a lower temperature than that of the walls. In order to draw up the warm air into the rooms, it would be necessary to have some means of extracting the air from the room, so as to draw in the warmed air. It would not always flow in of itself in this country. Thus you see that the warming by means of fresh air involves ventilation, and moreover requires, if it is to be thoroughly efficient, that your architect should have thought out the whole problem when he first plans the house, and before you build it; otherwise you are met with difficulties at every turn. In the method of heating by hot air alone you have this further consideration: The air in the heating chamber is necessarily at a given temperature, and your house is thus heated uniformly; but it may happen, in this climate especially, that you may want one room to be warm whilst another is cool. It is generally on this account that other methods of heating have been preferred. It is to these methods of heating that I would now direct your attention. These methods are hot-water pipes, or steam pipes, led from the fire, which is placed in some central position and arranged to accumulate the heat in those rooms or other places which it is desired to heat. I will at once say that the arrangements hitherto made for warming by either hot-water pipes or steam pipes have not fulfilled the conditions I have mentioned as being necessary to supply the comfort of the open fire. The method adopted is to accumulate a certain amount of heating-surface in a coil or nest of pipes, or in what is termed, in the United States, a radiator; but the plan of distributing the heat by means of a large flat surface placed close to the wall has been generally adopted. I do not wish to imply that it has not been thought of, because some few years ago, in an Exhibition of Sanitary Appliances, held at the Society of Arts, Mr. Pritchett, of Bishops Stortford, suggested something of the sort. The apparatus consists of a series of receptacles, or cases, for water. The cases themselves were formed of ordinary plates of corrugated metal, strongly put together, but having a small interval between them so as to unroll the water, as it were, into a film, and form a succession of reservoirs of water, about 30 in. in height, more or less, as is required, but only from $\frac{1}{3}$ in. to 1 in. in thickness, enabling them, therefore, to be placed continuously as a dado, or as a series of panels, round any room or building intended to be warmed, and occupying scarcely any appreciable portion of the space of the room or building. The corrugated form given to these reservoirs not only increases the area of the external surfaces, back and front, and imparts strength to the vessels, but secures a certain amount of friction in the action of the warmed water within the vessels, which predisposes it to part with its heat during its circulation. I have never seen this applied in practice on a large scale. These panels might conveniently form the dado of a room, and, if six feet high, would insure the comfort of the occupants of the room, as they would effectually prevent persons in the room from radiating the heat from their persons to the surrounding walls. Such panels all around the room would especially lend themselves to warming fresh air to be admitted into the room. Mr. Pritchett proposed that these should be warmed by the circulation of hot water; but it is certain that it would be more advantageous to employ steam to heat them if they

were established on a large scale. In England, steam is not much employed for heating. We are prejudiced against it. We fear accidents. It is, however, a method of conveying heat which is eminently suited to use on a large scale; and if we are to hope to abolish our smoke nuisance, it is by methods of heating on a large scale only that we may succeed. Steam heating is extremely simple in its application. Steam is easily led to great distances. Steam heated pipes are hotter than hot-water pipes, therefore their effect in warming the air in contact with them is also greater; and, therefore, when heating is required on a large scale, it will be found that it is more economical to use steam pipes than hot-water pipes; besides which, the pipes may be smaller, and thus in both ways expense is saved. Highly-heated steam pipes, moreover, radiate a large portion of their heat to the walls and furniture of a room. Heating by steam is universal in the United States, and the usual system may be described as follows: The steam is conveyed from the basement along pipes to the room or passage where it is wanted to be used, and there it is passed into a cluster or coil of pipes, called a radiator, which gives an enlarged heating surface. The cause producing the circulation throughout the pipes of the warming apparatus is solely the difference of pressure which results from the more or less rapid condensation of the steam in contact with the radiating surfaces; a partial vacuum of greater or less amount is thereby formed within the radiating portions of the apparatus, and the column of steam, or of water, equivalent to this diminution of pressure constitutes the effective head producing the flow of steam from the boiler, while the return current of condensed water is determined by the downward inclination of the pipes for the return course. Therefore, the flow pipe should be carried in as direct a line as possible from the boiler to the highest point; all the coils for heating should be placed on the return pipe, which should be laid in a uniformly descending line back to the boiler, so arranged as to prevent the lodgment of any condensed water on its way there, because, if condensed water lodges in the pipes, most unpleasant and startling noises result. It is a source of economy in steam heating that the condensed water should flow back to the boiler. This is what is called closed circulation, with separate supply and return mains, both of which extend to the furthest distance to which the heat has to be distributed. It is, however, possible to carry the steam and bring back the condensed water by means of a single main, which answers at once for both the supply and the return, either with or without a longitudinal partition inside it for separating the outward current of steam supply from the return current of condensed water. If more convenient, the return of the condensed water to the boilers may be dispensed with, and the steam may be applied in what is called the system of *open circulation*, where a supply main conveys the steam to the radiating surfaces, whence a return main conducts the condensed water either into an open tank for feeding the boiler, or into a drain to run to waste, or for use as hot water, the boiler being then fed from some other source; in either case suitable traps have to be provided on the return main for preserving the steam pressure within the supply main and radiators. The difficulty of steam heating lies in regulating the temperature of the pipes. With hot water you can have your pipes heated to anything you like from 50° to 180°, but with steam pipes it is different. The heat is got up very rapidly when the steam is turned on, and goes off very rapidly when turned off. There are various arrangements for regulating steam heating when applied to warm inflowing air. In the New York Hospital the incoming air is warmed by coils of steam pipes, and generally to a considerable temperature; but in order to prevent the warmed air entering the wards at too high a temperature, this hot air is passed into a mixing chamber, to which cold air can be admitted at will, so that the hot air can be mixed with cold air to the extent necessary to moderate its temperature before it is allowed to flow into the wards. There is, however, one great advantage possessed by coils of steam-heated pipes —they give out a larger proportion of radiant heat to the walls than is given by hot-water pipes. You can easily understand how much simpler it would be to warm Mr. Pritchett's dados and wall panelling by steam pipes carried through

them instead of by hot water. The next way in which heat can be applied is by means of gas. A gas jet warms any surface in contact with it. If, therefore, you enclose a gas jet in a metal case, and if you bring air to feed the gas burner from the outer air, and carry away the products of combustion also to the outer air, you can use the heat of the metal case to warm the surrounding air in the room, whilst the fumes of combustion from the gas will be taken outside and do no harm to the air of the room. Gas jets might thus be applied with the greatest ease to warm Mr. Pritchett's dados and wall panels, the gas jets being placed inside the dado, and the products of combustion carried to the outer air. Mr. Boyle has invented a very efficient method of applying gas to warm inflowing air at an ordinary ventilator. It is in use at the Guildhall. The fresh air inlet has placed in it a pipe which is coiled round. A gas burner is placed at the bottom of the pipe, separate from the air of the room; the products of combustion pass up the coiled pipe, and then down and out to the open air, the pipe being warmed by the heat they give out in their passage, and the fresh inflowing air being warmed by the pipe. Of course, in all these arrangements, air must be extracted by flues or fans, or some other method, so as to ensure a due circulation of air. But, however advantageous gas may be in the methods of its application to warming, and I do not hesitate to say that it can be easily applied so as to be hygienically perfect in that respect; moreover, you can apply your heat at the exact point at which you want it, for you can so arrange it as to give out a low degree of heat for warming fresh inflowing air, or to give out heat to warm your dados and prevent your own body losing its natural heat too rapidly by radiation; or you can use it to give out a high degree of heat, and thus to furnish radiant heat to warm you by direct radiation. It has only to be carefully adjusted to produce all these advantages, yet there is this enormous drawback to its use. At the price of 3s. 6d. a 1,000 cubic feet, it would cost to effect these things about four times the price of coal. I believe that if it could be supplied so as not to exceed double the price of coal, it might be economical to use it, because you can use it when and where you desire it. You can turn it off when you leave your room and turn it on again when you return, and in this climate, where our changes of temperature in winter are so rapid, a uniform heat applied everywhere often becomes oppressive. Let us consider for a few minutes what is the meaning of revolutionizing the methods of warming our houses in the way I now propose. We should not load our atmosphere with soot. Each of the fires in a house requires a separate chimney; and as, if the householder were determined to do all in his power to make the atmosphere impure, smoke which is arrested in the chimney flue in the form of soot is periodically pushed up out at the top of the chimney into the air, not only to the detriment of the occupier of the house, but to that of the neighbors—an arrangement which may be witnessed any morning in houses where chimneys are being swept. These inconveniences result from having separate fires in every house, and for each separate object. Let us consider, for a moment, the amount of labor and expense entailed by the mere supply of fuel upon this separate system. Take, as an example, one house of moderate size. The consumption of coal, at a low calculation, will be 24 tons a year, which would require 12 carts to convey it to the houses—or a street such as Eaton Place would require 12,000 carts to supply it with coal. These carts entail the presence of between 2,000 and 3,000 horses, and each horse causes, by the manure it deposits in the streets, an additional pollution of our atmosphere. When the coal is placed in the house, these 24 tons require to be carried up in coal-scuttles, each holding probably a quarter of a hundredweight. That is to say, that there would have to be carried from the cellar to various parts of the house nearly 2,000 coal-scuttles full of coal. The residue would have to be carried down again in the shape of ashes, probably to the extent of 400 coals-cuttles, independently of the proportion of ashes which get scattered from the fireplace about the room, and have to be cleaned up by the housemaid. In addition to this, the dirt engendered by the smoke and soot sent up into the atmosphere renders much additional cleaning necessary, and entails on the inhabitants of

London a vast expenditure on soap, and on repainting and redecorating our rooms. Indeed, the late Miss Garrett, who was celebrated for her skill and taste as a decorator of houses, told me she had no sympathy with the movement for the abatement of smoke, because she looked upon smoke and fog as specially sent by Providence for the benefit of decorators. The labor thus entailed is wasted force. It entails vast unnecessary labor and waste of fuel. Probably if the price of coal had remained high, as it was in 1875-6, we should ere now have begun to warm our houses in a more rational way.

But it is not on the ground of economy that I advocate a change. It is on the ground of purity of air. So long as we pollute the air with soot, not only is the outside air impure, but the air is so loaded with dirt that the careful householder excludes it from his rooms where possible. You would all be ashamed to supply your guests at a party with bad water. If you were equally ashamed, which you ought to be, to supply them with bad air, we should soon take measures to build our houses so as to keep up a continual flow of fresh air throughout our rooms. And then we should be rapidly compelled to take measures also for warming our houses in a way which would not pollute our atmosphere.

DRAINAGE OF LARGE MARSHES.

By C. E. HOLLISTER, of Lainsburg.

Transactions of the Michigan Association of Surveyors and Civil Engineers.

Marshes are not alike in all features, nor in the ease and manner of their drainage. Those lying nearly level with the great lakes would probably have to be diked and pumped out. But land in Michigan is as yet too cheap to warrant resorting to such an expensive process, and we will therefore omit all this class of swamps, and leave them to the engineer of the future.

The northern part of this peninsula was probably once an island, separated from the main land by a broad strait, extending from Saginaw Bay westerly through the region now known as the Saginaw and Grand River Valleys. This portion of Michigan is still low, and the country between the Saginaw and Grand Rivers, in Gratiot County, is perhaps the lowest point in the water-shed dividing the eastern and western slopes of the State. As this region is some 80 or 90 miles from either Lake Huron or Michigan, the water-courses have little slope, actually showing at some portions of their course, at a moderate stage, no fall in the surface of the water for one or several consecutive miles, and at other times having for 10, 15, or 20 miles no more than 10 to 14 inches fall per mile. Their channels are very tortuous, with many a needless mile through marshes and swamps.

Either the river channel must be deepened or the banks leveed and the marshes drained by pumping. Fortunately the former is much the cheaper in first cost, to say nothing of maintenance.

The problem in such cases is not so much what to do or how to do it, as it is to raise the necessary funds for the work. The present owners are not rich; had they been they would have bought upland; they have no idea that the land will be worth anything if drained, and the work requires a large expenditure all along the line, to which they will never agree except in the case of small streams of say 20 feet in width. The larger streams require some other than the common proceedings under the drain law.

It needs no argument nor any unusual experience to set forth the unhealthfulness of this state of repeated overflow and evaporation under the summer sun. But it seems that argument and facts and long continued agitation may be necessary to convince the people of the State that they can afford to deepen these river channels, and that a just consideration for the health and lives of those living near such streams will warrant

the expenditure and demands the assistance of the State in aiding and urging on this work.

In two noteworthy instances, the deepening and straightening of small streams preparatory to draining the large areas of wet land along their courses have been begun and carried nearly to completion in Clinton County, under the drain law, J. N. Smith as County Drain Commissioner planning and directing the work. The South Maple, or south branch of the Maple, has its source in a pond on sec. 16, T. 6 N., R. 1. W.; finds its way without much channel in a southerly direction through wide marshes for about 2 miles, then makes a sweep east and then northerly to the Maple River on section 4 of T. 7 N., R. 1. W. At the point where it turns east it is about 1 mile from the Looking-glass River, which at that point flows west in wide marshes.

Marsh land extends continuously from the creek to the river and drains into both. It is a noteworthy fact that, if the creek is cut to the depth of 5 feet from the surface of the marsh and a branch extended to the Looking-glass River, it will bring water from the channel of the latter river through the creek into Maple River. The creek drains about one-third of the Town of Victor, and about half of Ovid Township. In some places it flows through a narrow bottom or swale only a few rods wide; but most of the way through marshes or elm swamps $\frac{1}{8}$ to $\frac{1}{2}$ mile wide, the main line being about 17 miles long, and having two branches, one about 4, the other about 2 miles long, laid out and dug at the same time.

From the mouth of the creek, for a distance of 5 miles, the bottom as dug is to be 12 feet wide, and is to be deepened gradually as the valley widens until a depth of 5 feet from the surface is attained. At this point the drainage of about a square mile of marsh and the adjacent highlands enters the creek. Above this place the bottom is narrowed to 8 feet. About four miles up the stream is another branch of some miles in length. Here again the width at the bottom is contracted to 4 feet. At a point about 4 miles further up stream another branch comes in, and the width beyond is again reduced to 2 feet on the o m. The whole elevation from Maple River to Cedar Lake is about 95 feet.

It was proposed to make the bottom of drain 4 feet below the surface of the water at the stage when the preliminary survey was made, but the square mile of marsh that drains into it lies so flat that it was necessary to increase the depth to 5 feet. The work was put under contract in August, 1882, and most of the work was done by Jan. 1, 1883. The people along the line were amazed at the idea of going so deep, and thought it unnecessary; now they wish the ditch was deeper.

The cost was $13,000, and the number of acres of wet land which is assessed for benefit is about 3,300, making the cost about $4 per acre were it all to come from this land. About $3,000, however, were assessed to the two towns through which it ran, for benefit to health and highway benefits.

The very remarkable fall in this stream comes from its running north and towards the low part of the State mentioned before. The Cedar River empties into the Grand at Lansing, the Looking-glass at Portland, and the Maple at Lyons. All rise near together and flow nearly west. If then we cross a little west of the meridian, we find the Cedar about 25 feet higher than the Looking-glass, and the Maple about 120 feet below the Looking-glass.

We find still another class of marshes, such as the Chandler Marsh—large, flat; no creek flowing through them, but usually a creek leading from or heading in them. Usually the outlet is level for a long distance, so that we have a flat perhaps 4 or 5 miles long, sometimes double that, and we find that a large expense must be incurred in opening an outlet before we can begin to drain the marsh. When the water is drawn out, such marshes will settle from 1 to 2 feet. The Chandler Marsh has settled so that large stones project a foot, where in a natural state, all was water and soft mud, and no one thought of finding a stone within half a mile. The farther down the stream from the marsh, the shallower is the muck, the firmer the ground, and the less it will settle.

In making our calculations, we must, to save expense, go no farther down the stream than necessary; we must lay the

grade as flat as will work well, and go no deeper than necessary. Conditions have operated so powerfully upon parties in charge of such works, in all the cases which have come to my knowledge, as to over-shadow other less obvious but equally important matters, and have spoiled the job, making it necessary to go all over the same work time and again. Yet if we know and state just what is necessary, we often cannot get our plans adopted, because they look too large.

1. We must allow for the settlement of such marshes and the derangement of our grade. Hence we must cut deeper below and go farther down stream than at first seems necessary. *All fail here.*

2. We must go deep enough to allow the marsh to settle and still be able to drain the further edges of the marsh to a depth of 3 feet with a proper grade to the outlet.

3. The outlet must be large enough to carry the water off freely. We must look up the local water-sheds and see how much water we have to provide an outlet for.

The Perrin Marsh, in the town of Greenbush, Clinton County, is a case in point. For some years they raised quite good crops on the marsh, until the neighbors saw that marshes could be made productive, and had ditches dug running back 1 or 2 miles on each side, but especially on the south. As this is south of the low part of the peninsula, the surface slopes rapidly to the north. These side ditches have a great fall, and flood the marsh by bringing the water in too fast for outlet to carry it off. It also was not dug far enough down the stream. South of St. Johns is a similar case which fails for both these reasons, so that the man who was really the pioneer in reclaiming the marsh is completely drowned out and has lost his entire crop for two years on land where, before that time, he had raised most spring crops, hay and onions.

The Chandler Marsh also has no outlet. The main ditch stands full of water, as any of you who cross it on the J. L. & S. R. R. may see. Of course nothing can be done with land when the water stands in the ditches at a level with the surface.

The water which falls on a marsh is not that which makes the greatest trouble in draining them. It is that which flows on from the surrounding and higher lands, and also that which passes through the soil from the uplands, whether it comes in the form of springs or by an almost imperceptible soaking through the soil. If we run a branch on each side of the large marshes, we shall cut off all this water which comes from the sides. Otherwise it will flow over the surface and keep the whole marsh wet. This water may be drawn in by laterals, and, in small marshes, with but narrow water-sheds on the sides, this is the wiser course, but where a wide marsh is surrounded by a wide strip of flat land, we shall succeed better if we run near the edges of the marsh, and drain from each side of each ditch with laterals.

Some will object to this view, and say that the middle of the marsh will settle most, and hence be too low to drain into the side ditches. In fact, however, the middle of a marsh is generally the highest, and can settle most and yet not be too low; but the main reason after all is, there must be a drain along each edge to catch the soakage, or we shall not have it drained; and the cost will be less than to first make a main through the middle, and then laterals and shore drains. If the marsh is wide, the length of the laterals to bring in the shore water, especially if branch drains are needed as often as one in 40 rods, will be greater than the excess of the shore lines over a main in the center.

DISCUSSION.

Mr. J. J. Watkins did not believe that the bottom of a ditch settles; can see no reason for it, and his experience has proved that the top settles and the bottom rises, so that the ditch gets shallower from two causes. Use an 8-rod tape, and give distance in rods and links; commissioners liked it better.

Mr. S. N. Beden was certain Mr. Holland was correct; had tested the bottom many times by reference to a fixed bench mark; in one case when the levels had first been run by another party, and ditch constructed from these levels, he had occasion to run the levels again, and found a perfect agreement with the first levels on hard land, but on the marsh the result showed either an error of the first party, or that the ditch had settled 12 to

14 inches; believed that the bottom of the ditch had settled; put grade stakes down to grade; there can be no mistake, and they remain in the ditch to show the position of the bottom for all time; get them down by driving with a sledge on a turned and graduated hickory stick, with ferule to prevent splitting; no difficulty in getting them down 4 or 5 feet; consider a grade of 1.6 feet per mile as small as should be used; object to less than .06 foot per 100 feet.

Mr. W. B. Sears thought a better plan was to leave the top of each grade stake 3 or 4 feet above the grade line.

Mr. M. W. Bullock would like to know of a small dredge for such work; has had much difficulty with a floating bog; finally conquered it by constructing a flume in sections and sinking each one to place; prefer to drain small marshes by a center ditch.

Mr. B. F. Welles said that underneath the City of Marshall was a layer of sandstone so porous and dry that it would serve as an outlet to marshes if connected. In one case 10 drive wells in an area of 10 acres removed 10 inches of water in two days.

Mr. Hodgman—In some cases drive wells let water up instead of down; it depends entirely on the underlying strata. Many are dissatisfied with drainage because it is only half done; drainage might as well not be commenced as to be only half completed; had seen drains with a large volume of water work well on a level; get all the fall possible; thought that in marshes underlaid with clay the bottom would rise, and in deep muck marshes it would settle.

Mr. W. Appleton thought that the well method of drainage would always work if the well was made deep enough; had tried it with good success himself, and the well worked well for four or five years; he filled the well with small stone, but in time the silt from the marsh washed among them and ruined the well by filling the pores.

Professor J. B. Davis suggested that the well be made large, and that it be made deep enough, so that it should extend some distance into the water taking strata so as to get a side outlet; a settling well or basin should first receive the water and discharge from its upper surface into the drainage well.

Mr. T. W. Petter generally set stakes once in 20 rods, some commissioners prefer a grade table to a profile; must one be made? (The law requires one.)

Mr. C. E. Hollister believes in putting the drains on the edge of the marshes and not through the center; the water that does the injury comes almost invariably from the upland; would have them far enough from the edge of the marsh to allow the velocity of the water from the banks to be checked sufficiently to deposit debris before reaching the ditch. Clinton County has spent about $60,000 on county ditches the past year, but the principal construction has been done by hand. The cost for a ditch with an average depth of 5 feet, bottom width 8 feet, top width 24 feet, has been $5 per rod. The best results were obtained when each man could be induced to take the contract on his own land; had much difficulty with floating bogs. It is impossible to dig them out, when soaked with water; have had good success in freezing weather, by digging but little faster than the muck would freeze; the least grade depends on volume of water; for ordinary ditches should be 1 ft. per mile.

AN ABORIGINAL DWELLING.—A short time ago there was discovered in a marsh at Schussenried, in Wurtemburg, a well-preserved hut of the age of stone. The flooring and a part of the walls were intact, and, as appeared from a careful admeasurement, had formed, when complete, a rectangle, 10 meters long and 7 meters wide. The hut was divided into two compartments, communicating with each other by a foot-bridge made of three girders. The single door, looking towards the south, was a meter wide, and opened into a room 6.50 meters long and 4 meters wide. In one corner lay a heap of stones, which had apparently formed the fireplace. This room was the kitchen, "the living room," and probably a night refuge for the cattle in cold weather. The second room, which had no opening outside, measured 6.50 meters long and five meters wide, and was, no doubt, used as the family bedchamber. The floors of both rooms were formed of round logs and the walls of split logs. This, be it remembered, was a hut of the Stone Age. It may be safely presumed that the lake dwellings of the Bronze Age were larger in size and less primitive in their arrangements. At both periods the platform supporting the houses communicated with the shore by means of a bridge (probably removable at pleasure) and with the water by ladders. These ladders, as appears from an example found at Chavannes, were made of a single stang with holes for the staves, which protruded on either side.—*Contemporary Review.*

LIGHTHOUSE ILLUMINANTS.

From the "English Mechanic."

The great practical advances made of late years in the various systems of illumination led to the appointment of a committee to investigate the most modern appliances, and to report upon their relative merits, with special reference to their adaptability for lighthouse purposes. This committee, it will be remembered, was dissolved last year, for reasons which were publicly stated at the time, without having effected any practical work. The Board of Trade, however, subsequently afforded the Corporation of the Trinity House the opportunity of undertaking the investigation, and eventually intrusted the carrying out of the necessary experiments to the Elder Brethren. Thereupon a committee of the Elder Brethren was formed, which consists of the following members:—Captain Sydney Webb (Deputy Master of the Corporation of the Trinity House), chairman; Captain Nisbet, Captain Weller, Captain Burne, Captain Vyvyan, Admiral Sir Leopold McClintock, and Mr. Inglis, the secretary to the Corporation. Mr. Price Edwards, who was the secretary to the previous committee, acts in a similar capacity with regard to the present one. Sir James Douglas, the engineer to the Corporation, is advising the committee on points of detail, and the photometric observations are intrusted to Mr. Harold Dixon. Mr. Vernon Harcourt, F.R.S., is watching the experiments on behalf of the Board of Trade. The Corporation of the Trinity House is acting in conjunction with the Scotch and Irish Lighthouse Boards, and the representatives of various foreign Governments are taking an active interest in the experiments, which, we need hardly observe, promise in their results to prove of the highest importance to the maritime nations of the whole world.

Immediately upon their appointment the new committee took the necessary initiatory steps towards carrying out an elaborate and exhaustive series of experiments with three available illuminants—oil, gas and electricity. To this end they selected the South Foreland for the scene of operations, as being the most convenient and advantageous for the purpose. There are already two lighthouses there, known as the high and low lights, which are illuminated by electricity. By the forethought of the Trinity House engineer a surplus of engine power was provided at starting, and is available for the present electrical experiments. Then the surrounding country, being comparatively flat, or only slightly undulating, and the view unimpeded by trees or hedges, renders it a most eligible spot for taking observations far and near.

It is worthy of note that the South Foreland lighthouses, which were originally illuminated by means of coal fires, were the first in which electricity—carbon in a more refined and more highly intensified form—was adopted as an illuminant. This was in 1857, when Professor Holmes first submitted his system of lighthouse illumination by electricity to the Trinity House, and received permission to establish his apparatus in the high light, the system being afterwards extended to the low light. England was thus the first to adopt electricity for lighthouse illumination. The machinery and apparatus used for these two lights consist of four of Professor Holmes' magneto-electric machines—two for the high and two for the low light—which are both powerful and safe, producing a low tension current not exceeding 60 volts. They are, moreover, very reliable, costing little or nothing for repair. There are two horizontal steam engines of the single-cylinder type by Messrs. Hunter and English, each of 10 horse power nominal, but capable of developing 30 horse power each. Steam is supplied from a Cornish boiler 15 ft. long by 6 ft. diameter, and of which there are two, one being kept in reserve, as is also one of the engines, a single engine sufficing to drive the four Holmes machines, and those used in the experiments to which we shall presently refer. And here we may mention that upon our recent visit we found a very important permanent addition was being made to the South Foreland establishment. This consists of a

long one-storied brick building which is being erected by the Trinity Board for the purpose of conducting photometric experiments with very powerful lights, for which at present there exist no adequate means. This shed is 380 feet in length, and it will be fitted with the necessary appliances for light testing, and there in future all the large lights will be tested.

In connection with the experiments three temporary wooden towers have been constructed in a line landwards and bearing north-west from the permanent high light. These towers are marked A, B, and C, and are respectively used for the electric, the gas, and the oil light. Tower A is 245 feet from the high light, and tower B 180 feet from A; tower C being the same distance from B. The focal plane of all the towers is 15 feet below that of the electric high light, which is 380 feet above sea level. In the electric arrangements Baron de Meritens' arc lamps and magneto-electric machines are employed. At present there are two of these lamps and two of the machines in place, but another of each is to be added. The lamps are placed one above the other, or superposed, in the tower. The carbons used in them are compound—that is, they are made up of a number of small carbon rods of square section. The carbons in use at the time of our visit were 1½ inches square, and were composed of 49 small square rods, but since then the new Berlin Code carbons of Messrs. Siemens have been employed. The two machines for producing the current are placed in the engine house with the others, and, as we have stated, are driven by the same engine as the Holmes machines. Each of the De Meritens machines is arranged for working at one-fifth, two-fifths, three-fifths, and at full-power, the estimated intensity of the light from each machine at those powers being respectively 6,000, 12,000, 18,000, and 30,000 candles. The machines can either be worked singly or coupled up. Like the Holmes machines, those of De Meritens produce a low tension current, and are found to be very reliable in operation and inexpensive in maintenance. The arrangements for illuminating tower B consist of a small gasworks erected by Mr. J. R. Wigham, of Dublin, whose burners are used in the tower, his system having been adopted for lighthouses on the Irish coast. The gasworks were put up and the gas illumination is now being carried out under Mr. Wigham's supervision. The gas-producing apparatus consists of a small retort-house fitted with two benches of three retorts, the necessary purifiers, and a holder capable of containing 4,500 cubic feet of gas. The gas is passed through a meter placed outside the tower to the burners within it, and which are four in number. Each burner is composed of a series of concentric rings of jets, and the light can be started with a minimum power of 28 jets, and increased by gradations of 20 jets up to 108 jets, the full power of each burner, at which it develops 3,000 candle power. There are four of these burners superposed, and they can be used either singly or together, the lights being designated uniform, biform, triform, and quadriform, according to the number of burners in use at the same time. The object of the variations of power in the lights in all cases is to meet the varying requirements of the atmosphere.

In tower C, oil lights are used, and these are produced by means of burners of the recognized Trinity House pattern. For this purpose nothing further is necessary than a tank outside the tower containing a store of Scotch paraffine and the lamps and burners in the tower. The oil is supplied to the burner from the lamp under slight pressure by means of an arrangement similar to that adopted in obtaining hydraulic power, oil, of course, taking the place of water. The burners at present in use have six concentric wicks, each burner developing 720 candle power; but Sir James Douglas is preparing another burner of much higher power, having seven wicks, which will shortly be tried. The burners are arranged in three stages, and either a uniform, a biform, or a triform light can be exhibited as required. The burners are in duplicate on each stage, and by an ingenious arrangement the first lamp can be shunted out of position if necessary, and the second one lighted and shunted into its place without any appreciable loss of time. Sir James Douglas has also devised a very simple but effective arrangement for ventilating lighthouses by means of which the heated air is carried rapidly off, but the atmosphere of the

lighthouse is kept perfectly steady to a very high elevation in the coned roof, as was shown by experiments in this tower.

Such are the arrangements for producing the various lights. For testing them, carefully elaborated arrangements have been made. An overland route has been laid down as a line of observation for a distance of 2½ miles from the towers in the direction of Deal, and stakes have been driven at every 100 ft. At half a mile from the towers on this route is hut No. 1 for taking photometric observations, and this is more particularly intended for fog work. At 1¼ mile we come upon hut No. 2, which is likewise fitted with photometric apparatus. At the limit of the range is the third hut, each hut being conveniently fitted up for the residence of the official in charge. Arrangements have also been made for observations to be taken at the various coastguard stations within the focal area, at Ramsgate and other contiguous places, and at various points out at sea, including the Gull and Varne light vessels, which are respectively 8 miles N.E., and 12 miles S. W. distant from South Foreland. The observers are supplied with books for recording their observations in tabular form, which will ultimately be collected and their contents collated for the information of the committee. The books contain directions as to the method of procedure in making observations. Observers are also provided with charts for land and sea observations, showing the illuminated areas to the north and south of South Foreland. The committee have quarters at St. Margaret's, contiguous to the experimental towers, where one of their body will always be in residence. Ranging over so wide an area as they will, and involving so many investigations as they do, we need hardly say that the experiments will occupy several months, probably five or six. Every illuminant and variety of burner adapted for lighthouse illumination will be tested under every possible condition pertaining to itself and to the atmosphere. The most important point as regards atmospheric conditions will be fogs, which will have very careful consideration. Upon the occasion of our recent visit splendid lights of varying intensities were produced at night by each of the three systems under trial. The preliminary photometric observations appear to indicate that the electric light in comparison with either the gas or the oil light is as the sun is to a candle. This, however, is but natural, but, as a result, it has to be considered in connection with a variety of other conditions into which it is not only unnecessary, but inexpedient for us to enter. The experiments have at first been confined to the testing of apparatus and contrivances already in use. A further stage will be devoted to any other burners and appliances which shall be submitted to the committee, and after inspection by them shall be adjudged suitable for lighthouse illumination. It is thus open to the whole world to assist in promoting a movement of the first importance, which in its results cannot fail to prove of the highest value to every maritime nation.

THE SOFTENING OF WATER.*

By BALDWIN LATHAM, M. Inst. C.E., F.G.S.

From "The Building News."

From the remotest period of antiquity, the art of softening water for the purposes of washing and cleansing appears to have been known and adopted. Soap is very largely used, or rather wasted, in many places in the present day for softening water, for which it is now well understood that no useful effect in washing is produced until sufficient soap has been used as to soften the water. For the purposes of this investigation water may be divided into two classes, hard and soft. Hard water is a water which contains salts of lime, magnesia or iron, and sometimes an amount of free carbonic acid. A hard water is one that destroys soap in washing, while a soft water is one that does not destroy soap. A soft water

* A paper read at the Society of Arts Water Supply Conference, July 25, 1884.

may derive its properties from an absence of earthy salts, or it may have become soft by reason of the presence of certain alkaline salts in the water, notably the salts of soda and potash. Hard waters may be divided into two classes, those which are permanently hard and those which are temporarily hard. Generally a single sample of naturally hard water partakes of both these properties. A water which is said to be temporarily hard becomes soft by boiling, as the hardness is due to salts of magnesia or lime dissolved in the water by the agency of carbonic acid, or due to the presence of this gas in a free state in the water. Under either circumstances the effect of boiling the water a sufficiently long time is to drive off the carbonic acid gas, and a natural softening of the water takes place from the absence of this gas, and the earthy salts that have been held in solution by it in the water. Water that is perfectly hard derives this property from the presence of the same salts as are in water temporarily hard, but instead of being combined with carbonic acid they are combined with sulphuric acid, and to soften water that is permanently hard requires very different conditions than is the case with waters that are only temporarily hard. The qualities of a good drinking water have been described as: 1st. Freedom from vegetable and animal matter. 2d. Pure aëration. 3d. Softness. 4th. Freedom from earthy, mineral or other foreign matter. 5th. Coolness and delivery at the minimum temperature. 6th. Lucidity or clearness. 7th. Absence of taste and smell. Although many authorities insist that for the sake of health a soft water is beneficial, on the other hand, there are those who contend that there is no evidence whatever to show that even a hard water has any influence upon health. It is clear, so far as the health statistics of this country are concerned, that, if anything, the results come in favor of persons inhabiting districts having hard waters. On the other hand, it has been thought that particular diseases which affect particular localities, such as cretinism and goitre, are due to certain salts of magnesia which have been found in the waters of the district. Some waters which are of remarkable softness, in which the softness is due to the presence of certain alkaline salts, especially those of soda, may be quite unfit for drinking purposes. A type of this water is found in the well supplying the Trafalgar square fountains, as it is stated that the large amount of soda contained in it, if taken habitually, acts medicinally upon the kidneys. It is also unfit for washing, as the water is liable to destroy certain colors and stains glass. It is said to be unfit for bathing, as the soda combines with the oily matter of the skin, producing a roughness and liability to chapping. Water, however, which is naturally soft, or which has been softened by means of a process like Dr. Clark's, which does not add any new element to the water, has great advantages for many purposes. It prevents incrustation of steam boilers and household utensils, it results in a saving of fuel, less wear and tear in washing linen, and in the labor of cleansing; it saves soap in all washing and cleansing operations, the water cleans better, and gives a better color to linen, and it is also stated to lead to greater economy in tea-making and brewing, but whether this is correct or not is very doubtful, as water used for such purposes is always boiled, and when used in that state should be as soft as softened water. The processes which have been used both in ancient and modern times, may be comprised under the heads of boiling, chemical processes, distilling, exposure, freezing.

SOFTENING BY BOILING.

The effect of boiling water is to liberate the carbonic acid which holds certain alkaline salts in solution, and on the liberation of the acid these salts are precipitated, and form the coating which furs our kettles, accumulates in our boilers, blocks the circulating pipes of our water-heating apparatus, and is often a source of danger, and always of expense. The effect of boiling water in order to soften it can only be secured when this operation is sufficiently prolonged. The commissioners appointed to inquire into the chemical properties of the water of the metropolis in 1851, made some experiments on the effects of boiling an artificially prepared hot water containing 13.5 grains of carbonate of lime per gallon, and it was found to decrease in hardness from 13.5° to 11.2° by being heated to the boiling point; after boiling for 5

minutes it was reduced to 6.3°, for fifteen minutes to 4.4°, for thirty minutes to 2.6°, and for one hour to 2.4°, so that the softening effect does not take place at once, but a prolonged boiling is required in order to produce the greatest degree of softening. In order to get rid of the temporary hardness of water, sharp boiling for not less than twenty minutes is requisite, but boiling water does not remove the hardness occasioned by the salts, which are neutral; in fact, the permanent hardness of the water is increased by boiling, as all the water evaporated leaves a concentration of the neutral salts in the remaining water. It has also been shown that the alkalinity of water is more after boiling than when softening has been produced by an alkaline salt, such as lime; but both have the effect of reducing the hardness to about the same degree. This increase of alkalinity after boiling is attributed to the concentration of the neutral salts consequent on the loss by evaporation. The temporary salts held in solution by water are precipitated by boiling, and it is these precipitated salts which cause the furring of kettles, hot-water boilers, steam boilers, and hot-water pipes, and have led to the adoption in certain cases of means either for retaining the salts in solution in the water, or of preventing their deposit in steam boilers, but as a rule with only partial success.

CHEMICAL PROCESSES OF SOFTENING WATER.

In a paper read before the Literary and Philosophical Society of Manchester, in 1781, by Thomas Henry, F. R. S., a description is given of a mode of preserving sea water by means of quick lime, in which the author pointed out that the earthy base of magnesia was precipitated in sea water by lime, and its place taken by a calcareous salt. He also referred in this paper to the well-known action of quicklime on common water as a preservative. The effect of the lime, doubtless, upon the sea and fresh water was to induce abundant precipitation, which dragged down with it certain organic impurities, and as a consequence the water remained free from putrefactive influence afterwards, as was clearly shown in the course of his experiments. The first patent for purifying water by chemical agency in this country was taken out in 1838, for precipitating by muriate of zinc and salts of soda, the latter salts precipitating the zinc from the water, leaving the water in a purified state. In 1841, Dr. Thomas Clark, of Aberdeen, took out a patent for his well known and beautiful process for softening water, and which has, more or less, been the basis of all other patented processes of this description which have been adopted since that period. Dr. Clark thus described his process in May, 1856:

"In order to explain how the invention operates it will be necessary to glance at the chemical composition and some chemical properties of chalk, for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every one pound of sixteen ounces, of lime, nine ounces; carbonic acid, seven ounces. The nine ounces of lime may be obtained apart by burning the chalk, as in a lime kiln. The nine ounces of burnt lime may be dissolved in any quantity of water not less than forty gallons. The solution would be called lime water. During the burning of the chalk to convert it into lime, the seven ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda water when dissolved in water under pressure. Now, so very sparingly soluble in water is chalk by itself that probably upwards of 5,000 gallons would be necessary to dissolve one pound of sixteen ounces; but by combining one pound of chalk in water with seven ounces additional of carbonic acid—that is to say, as much more carbonic acid as the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved is called bicarbonate of lime. If the quantity of water containing the one pound of chalk with seven ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same hardness, as well water from the chalk strata, and not sensibly different in other respects. Thus it appears that one pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical

changes: soluble by being deprived entirely of its carbonic acid, when it is capable of changing water into lime water, and soluble by combining with a second dose of carbonic acid, making up bicarbonic of lime. Now, if a solution of the nine ounces of burnt lime, forming lime water, and another solution of the one pound of chalk and the seven ounces of carbonic acid, forming bicarbonate of lime be mixed together, they will so act upon each other as to restore the two pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present, for the simplicity in this explanation. A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1½ grains would remain. In other words, water with 17½ degrees of hardness arising from chalk can be reduced to 1½ degrees, but not lower. These explanations will make it easy to comprehend the successive parts of the softening process. Supposing it was a moderate quantity of well water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain one pound of chalk, and would fill a vessel 4ft. square by 4ft. deep. We could take 9 ounces of burnt lime made from soft upper chalk; we first slake it into a hydrate by adding a little water. When this is done we would put the slaked lime into a vessel where we intend to soften water gradually. Add some of the water, in order to form lime water. For this purpose at least 40 gallons are necessary, but we may add water gradually until we have added thrice as much as this; afterwards we may add the water more freely, taking care to mix intimately the water and the lime water or lime. Or we might previously form saturated lime water, which is very easy to form, and then make use of this lime water instead of lime, putting in the lime water first and adding the water to be softened. The proportion in this case would be one bulk of lime water to ten bulks of the hard water. It is of importance that the lime or lime water, that is, the softening ingredient, be put into the vessel first, and the hard water gradually added, because there is thus an excarbonate of lime produced in the process more easy. But what you will wish to know now is by what mark is the conductor of the process to find out when there is enough of water to take up the last of the excess of lime, so as to be enough, but no more. This is done by what has been called the silver test, the only test necessary to the operator after the process is fairly set a-going. This test is a solution of nitrate of silver in twice distilled water, in the proportion of an ounce per pint. In making use of the silver test in ordinary water we get a white precipitate; but if the water have in it a notable excess of lime water, there is a light reddish brown precipitate produced; but if the excess be very slight, we only get a very feeble yellow precipitate. The way we make use of the test is to let two or three drops of it fall on the bottom of a white tea cup; then add the water somewhat slowly; then, if there be the slightest excess of lime, a yellow color will show itself."

It may be here mentioned that a more delicate test than the silver test, for ascertaining if there is an excess of lime in the water, consists in using a solution of cochineal, the natural color of which is yellowish red, which is turned violet in the presence of alkalies; and other agents are now used to show, by distinct color or its absence, if there is an excess or not of lime in the softened water. According to Dr. Clark's scale, 1° of hardness means that there is one grain of chalk in a gallon of water. According to the scale introduced by Dr. Frankland, in the sixth report of the Rivers Pollution Commissioners, parts per 100,000 are used, or one grain of chalk in 100,000 grains of water, so that it is necessary, in considering the reports of the Rivers Pollution Commissioners, to bear in mind this difference of degrees of hardness. To reduce the hardness to parts per gallon, or to the Clark scale, it is necessary to multiply by 7 and divide by 10. Hard water decomposes soap. The amount of soap ascertained by Dr. Clark to be wasted before softening the water is equivalent to 2 ounces for each degree of hardness for every 100 gallons. Dr. Clark introduced a soap test, or a means by which a solu-

tion of soap is made to at once indicate the degree of hardness of a water. When pure chalk is burnt into lime, one pound is converted into 9 ounces of lime, and this quantity is soluble in 40 gallons of a water. Beyond this, lime is not soluble in water, so that clear lime water always possesses a known composition. This amount of lime is equivalent to 98.43 grains per gallon. As one particle of lime will remove $\frac{1}{56}=1.77$ of chalk, it follows that $98.43\times1.777=174.9$, or the number of gallons of water 1° of hardness which one gallon of lime water will soften. In practice, however, while theoretically 175 gallons of water of 1° of hardness may be softened by one gallon of lime water, owing to the impurities in the lime, probably not more than 140 to 150 gallons would be softened, so that, to arrive at the amount of lime water necessary to soften hard water, if we divide 150 by the degrees of hardness according to Clark's scale, it will, generally, roundly represent the number of gallons of water which can be softened by one gallon of lime water. Neither by boiling nor by the lime process can all the hardness which is termed "temporary hardness" be removed; in fact, a small quantity of chalk, to the extent of one part in 5,000 parts, is insoluble in water, and still remains in solution after the process. In practice, however, 10-11ths of the whole of the temporary hardness may be removed by the lime process. In carrying out the Clark process, the lime water is usually applied, owing to the fact that it is a standard liquid containing a known quantity of lime, although cream of lime is sometimes used with advantage. Large tank space is required to carry out the Clark process, three tanks ordinarily being required, one for filling up, another for drawing down, and a third in reserve while cleansing is going on, and each tank should hold a day's supply. It is important to know that the salts of iron may be readily removed by the application of lime. This the author found in the case of a waterworks at Horsham, where the water was so highly charged with iron that everything it touched was discolored; but by the application of lime the whole of the iron was removed. It should also be noted that the process has a marked effect in removing organic matter from water. This was shown by the Rivers Pollution Commissioners, and by the analysis published by Professor Wanklyn, especially in the marked diminution in the amount of albuminoid ammonia. The great objection raised against soft water has been its liability to produce lead poisoning; but the concensus of opinion is that water softened by the Clark process is not liable to attack lead, which is a point of very considerable importance in favor of the process. Dr. Clark's process was first carried out by the Woolwich and Plumstead Waterworks Company, where it was shown that the water was successfully softened from 23° to 7°. These works were subsequently bought by the Kent Waterworks Company, and the process of softening the water was discontinued. In the course of experiments made in softening various waters, it was observed that, if the water was at all tinted, the softening process did not clear it; but there was a tendency for the matters separated to remain in suspension in such water, so that it was considered expedient, in softening river water, that the water should be filtered until quite bright before it undergoes the softening process. In 1852 a patent was applied for (W. B. Bowditch) to treat water with clay and alkali, and subsequently filtering. Mr. Philip H. Holland, M. R. C. S., late inspector to the Burial Acts Office, suggested as an addition to the Clark process the use of oxalate of ammonia or soda to further reduce the hardness of the water after treatment by this process. The use of carbonate of soda for softening water has been known throughout the whole country by tea-makers from an early period. This salt added to water acts on the bicarbonate of lime and magnesia, and precipitates chalk and carbonate of magnesia. It also decomposes the sulphates of lime and magnesia, precipitating the lime and magnesia, while the soda remains in solution, so that the permanent hardness of the water is reduced by the use of this salt. The process, however, of using soda is much more expensive than the ordinary lime process, about $4\frac{3}{4}$ times as much soda being required to produce the same results as in the case of lime. An old recipe for softening water, and useful for some do-

mestic purposes, is as follows: Dissolve 6lbs. of pearlash, or sub-carbonate of soda, in a gallon of soft water, boil the solution, and when boiling add 2ozs. of soap, and stir until all the soap is dissolved. When this solution is added to water to be softened, the carbonate of soda and the soap combining with the salts, producing both temporary and permanent hardness, form an insoluble compound by the combination with the soap, which coagulates and rises to the surface of the water, and may be skimmed off. As any of the earthy alkaline earths may be used instead of or in addition to, lime, it is not surprising that, since the date of Clark's patent, numerous patents have been taken out for softening and purifying water in which lime, in combination with other alkaline earths, have been proposed. For example, in 1849 Mr. John Horsley took out a patent for the use of calcined or caustic barytes, phosphate of soda, oxalic acid, or preparations of these substances. In 1850, lime, in combination with chloride of barium was patented. In 1852, hydrate of potash and hydrate of soda, clay and alkalies were the subjects of separate patents. In 1853 and 1854, hydrate of barytes and hydrate of strontia formed the subject of patents. In 1855 a patent was taken out for a powder containing oxalate of ammonia, peroxide of manganese, and charcoal. In 1856, silicate of soda, in combination with carbonate of soda, was patented. In 1856, bicarbonate of soda and oxalic acid, in crystals, were again proposed to be used. In 1856 and 1857, carbonic acid was proposed to be introduced in conjunction with hydrate of lime. In 1860, bicarbonate of soda and silicate of soda were again twice patented. In 1862 the ordinary lime process was repatented. In 1863 the use of chloride of barium was patented. In 1865, hypermanganate of potash, carbonate of soda, alum and neutralized aluminite, or a solution of iron was proposed; and in another patent, sesqui-sulphate of alumina was proposed as a means of purifying water. In another patent, taken out in 1865, the use of soda and lime is again patented. In 1866 a patent was taken out by a Mr. J. W. Tobin for an improvement on the Clark process for mixing the lime and filtering. In 1866 the use of chlorine and permanganates, in combination with any alkaline earth, was patented. In 1867 a patent was taken out for a preparation in a portable form, consisting of marshmallow, linseed, bran, starch, gum, or any softening ingredient, for the purpose of softening water for ablution purposes. In 1868, the use of barytes was again patented, and the precipitate removed in vessels of a cellular form. In 1869, the use of steam applied to water as a means of softening it was patented, the particles subsiding on shelves arranged in a vertical vessel. In 1872, unslaked lime and sulphate of soda were patented as a means of purifying water. In 1873, the lime process, in conjunction with a mixing and filtering arrangement, was patented; also lime, carbonate of soda, chloride of barium, or other reagent in conjunction with filtering. In 1874, the treating of water with lime and carbonate of soda in combination with filtration was proposed. In 1875, the lime process, pure and simple, and in combination with other reagents and filtering, was patented. In 1876, the lime process in combination with filter presses was first patented by Mr. Porter. In 1877, the use of oxide of magnesia and basic carbonate of magnesia was proposed; also the use of a carbonate of potassa, silicate of soda and niter cake, used separately or combined. In 1878, a patent was taken out for combining bicarbonate of soda with the lime process, and filtering upon the Porter-Clark plan. In 1879, Mr. Porter took out an additional patent for carrying out automatically the softening and purifying of water. In the same year phosphoric acid and phosphate of lime were proposed as a means of softening water. In 1880, the means of automatically carrying out the softening process, and adjusting the qualities by means of an arrangement of ball valves in a cistern, was patented. In 1881, Mr. Porter took out a further patent for the automatic regulation of the supply of the solution of lime. In 1881, Mr. Atkins took out a patent for treating water with lime, and subsequently filtering through a specially-constructed filter. In 1882, an apparatus for softening and clarifying water was proposed, in which sloping shelves in a vertical vessel were used, the water entering the bottom of the vessel and flowing off at the top; or

concentric cylinders overflowing from one to another might also be used with the same object. In 1883, Messrs. Gaillet and Huet's apparatus for softening water was patented, consisting of sloping and V-shaped shelves in a vertical vessel, the water entering at the bottom and flowing out at the top. The use of steam and caustic soda was also patented. A patent was also taken out for the use of phosphate of soda, and an apparatus for measuring the water and lime to be used in the softening process.

MODERN INVENTIONS FOR SOFTENING WATER.

The modern inventions for carrying out the Clark process may be described as the application of machinery to the saving of time, space and labor. Of those in general use, dealing with them in the order of date, the Porter-Clark process comes first. In the ordinary Clark process, lime water, in known quantity, is first admitted into a tank, to which the water to be softened is added. However, in some cases, the lime water and the hard water are allowed to flow in together into the tank, but it was considered by Dr. Clark to be an advantage, in carrying out this process, for the hard water to be brought into contact with an excess of lime water in the first instance, which was led into the tank before the water to be softened was added. In the ordinary Clark process, not less than 16 hours were required for the softening and subsidence of the matters separated from the softened water. In the Porter-Clark process, instead of allowing the particles of carbonate of lime to separate and subside, a brisk agitation is maintained, so that these particles remain in suspension, so as to permit chemical reaction with the lime, and the purification of the hard water which, when completed, is passed onward to filter presses, where the carbonate of lime adheres to the filtering cloth. The subsequent operations of filtering through the deposit on the cloth then takes place, and the water is passed away at once in fit state for use, so that the process is continuous in its action, and may be carried on just as quickly as water may be pumped from a well, provided the apparatus is of sufficient capacity to allow time for the water to remain in contact with the lime in passing through the machine. The lime in this case is passed through horizontal cylinders, which are termed lime churns, and is constantly churned up with water, and the lime water so made is, by suitable arrangements, allowed to mix with the ordinary water in proper proportions, after which it is again agitated. Mr. Porter has also an apparatus by which, instead of using ordinary filter presses, he can use filter frames, and where power is not available, he also suggests a means of working the process without such power. In some cases the power obtained from the pressure of the water is utilized for working the apparatus. An apparatus of this description may be seen at the Camden Town locomotive sheds of the London and North-Western Railway, and the apparatus may also be seen at work within the Health Exhibition.

THE ATKINS PROCESS

Is also a modification of the Clark process, by which the space formerly required is reduced. The lime is put into a vessel where lime water is formed, and this water is allowed to mix in its proper proportion with the water to be softened in a specially-arranged mixing vessel, after which it passes into a reservoir of small dimensions. From this reservoir it is conveyed to filtering vessels which contain a special arrangement of filter, consisting of a series of chambers mounted upon a central hollow shaft, these disc chambers being covered with prepared canvas, upon which the deposit of chalk, &c., adheres, and through which the softened water filters. The filters are cleansed by means of revolving brushes. The apparatus does not require power to maintain it while at work, the only power used being that necessary to give motion to the brushes when the apparatus is cleansed. The system may be seen at work at the Henley-on-Thames Waterworks, and at other places.

IN THE PROCESS OF M. MAIGNEN

A powder is used which the inventor calls "Anti-calcaire." This powder is made of variable composition in order to suit the special characteristics of the water to be treated, the ingredients used for ordinary hard water being lime, soda and alum in suitable proportions. In the apparatus, which is at work at the International Health Exhibition for soft-

ening water for some of the breeding tanks, the water entering the apparatus gives motion to a water-wheel, which in its turn works an arrangement for distributing a given quantity of the softening agent, and causing it to pass into the water. The water is then allowed to subside in a small tank, and is eventually filtered through filters covered with asbestos cloth, the basis of the filter being similar to that of the "Filter Rapide." A part of the carbonate of lime and magnesia deposited from the water adheres to the filtering surface, and the softened water filters through it. The apparatus may be seen at work in the Exhibition.

THE PROCESS OF MESSRS. GAILLET AND HUET.

In this process, patented in February, 1883, the patentees make use of certain known agents, the patent itself applying to the apparatus used for the purpose of producing the results after the chemicals have been applied. The agents they propose are lime and caustic soda. Whenever the water contains organic matter, they use salt of alumina or iron in addition. Iron, however, is not recommended in any case where the water is required for washing purposes. The apparatus consists, virtually, of a series of tanks in duplicate, in which the chemicals are mixed, and these enter a vertical pipe in proper proportion to the water to be softened, and which communicates with the bottom of an upright chamber divided by a series of sloping shelves through which the water gradually works up in a zig-zag path. These shelves slope in one direction and are of V-shape, so that as the deposit takes place it accumulates at one point, at which there is an opening ordinarily closed by a tap, and when any tap is open the deposit on the sloping shelf communicating with it is washed out. The apparatus appears to be extremely simple in its design, but its efficiency has yet to be tested, although it is at work at Messrs. Duncan's, Victoria Docks.

PURIFICATION BY DISTILLING.

Purifying water by the process of distillation has been used from remote periods in order to produce absolutely pure water, and during the last forty years very great improvements have been adopted in order to bring this process into more general application in connection with the purposes of water supply. The difficulty of obtaining absolutely pure water is practically exemplified by this process, for in attaining this result, unless the water is distilled some two or three times, and every time a large proportion of the residue is discarded, pure water cannot be obtained. In the case, however, of water distilled for dietetic purposes, it is not necessary to carry out the process to the extent required in procuring water for some chemical purposes. It has generally been considered that distilled water lacks aeration, and on this account it has been strongly recommended that it should be filtered. The great improvements in the processes of distillation are due to Dr. Normandy, whose first patent, taken out in 1851, has been improved upon by many subsequent patents. The process has been adopted with the greatest advantage in many of our ocean steamers, and the preservation of the health of the crews and passengers visiting countries liable to the ravages of epidemic disease is, in great measure, due to this process. It is generally believed by many high sanitary authorities that if this system were adopted at malarious stations, one of the largest channels by which infection is disseminated would be effectually closed.

SOFTENING BY EXPOSURE.

The exposure to the air of water containing salts which are held by carbonic acid causes a loss of carbonic acid. Water of deep wells which has been in contact with chalk and other rocks often contains free carbonic acid by exposure, especially under the inequalities of diurnal temperature, the original charge of ground air is got rid of, and atmospheric air takes its place. On exposure to air, hard waters are especially liable to develop vegetable growth. A few days' exposure of very hard water in the summer time will soon develop green confervoid growth, and so soon as this growth takes place, carbonic acid is rapidly used up by it, so that the bicarbonates in the water are soon converted into simple carbonates, and are precipitated. Water, therefore, exposed to air undergoes a chemical metamorphosis; the bicarbonates of lime and magnesia are converted into carbon-

ates, and are precipitated, and it is in this way that exposure assists in softening water.

SOFTENING BY FREEZING.

Ice taken from hard or other impure waters, if found to be perfectly crystalline and free from air bubbles, will produce, on melting, a water as soft as that of distilled water. If, however, the ice contains air bubbles or cavities of any description, such water will not be entirely pure. Some years ago the author made an extensive series of experiments upon the degree of purity which might be arrived at by freezing water, when it was shown that the act of freezing may be carried to such an extent as to produce in the remaining water, a precipitation of the salts in solution, but ice frozen upon very superficial water was found very liable to have the impurities frozen in it which adhered to the under sides of the ice, and which became embedded in it by subsequent freezing, while water which has been largely deprived of air by boiling or exposure, upon being frozen, if perfectly crystalline, will produce absolutely pure water. Several patents have been taken out with a view to freezing sea water so as to furnish a supply of fresh water on board ship, but such processes will not compete, from an economical point of view, with the process of distillation.

GEOLOGICAL.

The geological formations which furnish water of a quality suitable to be softened are those of the dolomitic or magnesian limestone, which gives great hardness to water, for while salts of lime render water hard and troublesome in washing, those of magnesia cause the water to curdle and render it considerably more disagreeable for washing and ablution. The mountain limestone, which is ordinarily of an impermeable nature, does not yield water of such a hard quality as those of the magnesian limestone. The waters of the oolite and chalk are chiefly hard from what has been termed temporary hardness, that is due to the presence of bicarbonates of lime and magnesia in the water, which may be got rid of by boiling, or by the lime process. The waters of the new red sandstone and Permian beds vary considerably in hardness; many of them have a considerable permanent degree of hardness, but there are none of them which may not be softened to a great extent by the adoption of the lime process, while this process, in combination with the other alkali earths, such as soda, when the water is not intended to be used for dietetic and washing purposes, will still further reduce the hardness of these waters. The surface wells of the country, usually sunk in drift covering various geological formations, furnish water of various degrees of hardness. Scarcely any such wells yield a soft water, and in most instances, when these wells are sunk in populous places, in addition to their natural hardness, the waters are highly polluted, and such waters ought never to be used for dietetic purposes, unless they are first boiled.

A RECENT writer in the *North China Herald* discusses the part played by mercury in the alchemy and *materia medica* of the Chinese. Cinnabar was known to them in the seventh century before the Christian era, and its occurrence on the surface of the earth was said to indicate gold beneath. Their views on the transformation of metals into ores and ores into metals by heat and other means took the form of a chemical doctrine about a century before Christ, and there is now no reasonable doubt that the Arabian Geber and others (as stated by Dr. Gladstone in his inaugural address to the Chemical Society) derived their ideas on the transmutation of metals into gold and the belief in immunity from death by the use of the philosopher's stone from China. Among all the metals with which the alchemist worked, mercury was pre-eminent, and this is stated to be really the philosopher's stone, of which Geber, Kalid, and others spoke in the times of the early Caliphs. In China it was employed excessively as a medicine. On nights when dew was falling, a sufficient amount was collected to mix with the powder of cinnabar, and this was taken habitually, till it led to serious disturbance of the bodily functions. In the ninth century an Emperor, and in the tenth a Prime Minister, died from overdoses of mercury. Chinese medical books say it takes two hundred years to produce cinnabar; in three hundred years it becomes lead; in two hundred years more it becomes silver, and then by obtaining a transforming substance called "vapor of harmony" it becomes gold. This doctrine of the transformation of mercury into other metals is 2000 years old in China. The Chinese hold that it not only prolongs life, but expels bad vapors, poison, and the gloom of an uneasy mind.

MAXIMUM STRAINS IN JOINTED BOW GIRDERS.

By EMMERICH A. WERNER, C. E.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

External Forces in Bow Girders with Joints.

For the correct calculation of the strains in any girder, it is necessary to know the external forces acting upon it, and the greatest values they can assume.

To show how to find these external forces and their greatest values in bow girders with joints is the object of this treatise.

The external forces consist of the loads (primary forces) and the reactions of the abutments (secondary forces).

If only *vertical* reactions act upon the girder, it is called a *beam*, if *vertical and horizontal* reactions are acting, it is called a *bow girder*.

As there are only three equations expressing the equilibrium of the forces of a rigid system in the plane, it is only possible in the case of a beam on *two* supports to find the reactions of the abutments directly.—In all other cases the necessary equations for expressing the reactions of the abutments must be found by other means.—

The simplest way is the use of joints.—The joint presents no difficulty as to the construction, and gives on the other side, perfect security for correct acting.—The moments necessarily become zero in the joints.

ABC represent *that line of a bow girder, in which the horizontal reaction of the abutments, or the thrust of the bow is acting.* I will call it *the line of thrust.*

The bow has joints on the abutments and in the crown. A,B are the abutment joints, C the crown joint.

Let the line ABC be referred to rectangular co-ordinates, with the origin in A.

$Q Q_1 H$ = be the vertical and horizontal reactions of the abutments.

l = span of girder.

f = ordinate of the crown joint, at the same time greatest ordinate of the bow.

$G_1 G_2 G_3$ = sum of all the loads from $x=o$ to $x=x$; from $x=x$ to $x=\frac{l}{2}$ and from $\frac{l}{2}$ to l.

$g_1 g_2 g_3$ = abscissae at the points of application of $G_1 G_2 G_3$.

M_x = sum of the moments of all the forces in the point x.

V_x = the vertical reaction of the abutment, less G_1.

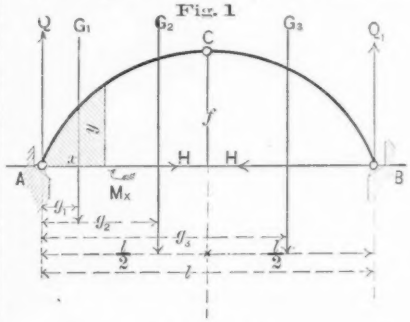
R_x = sum of the shearing forces *normal* to the *line of thrust* in the point x.

S_x = sum of the *vertical* shearing forces in the point x.

μ_x = angle of the tangent of the line of thrust in the point x, with the x axis.

μ_f = angle of BC or AC with the x axis.

Fig. 1



$$Q_1 = \frac{G_1 g_1 + G_2 g_2 + G_3 g_3}{l} \quad . \quad . \quad . \quad . \quad (1)$$

$$Q = G_1 + G_2 + G_3 - Q_1$$
$$= \frac{G_1 (l-g_1) + G_2 (l-g_2) + G_3 (l-g_3)}{l} \quad (2)$$

$$Hf = Q_1 \frac{l}{2} - G_2 \left(g_2 - \frac{l}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$H = \frac{G_1 g_1 + G_2 g_2 + G_3 (l-g_3)}{2f} \quad . \quad . \quad . \quad (4)$$

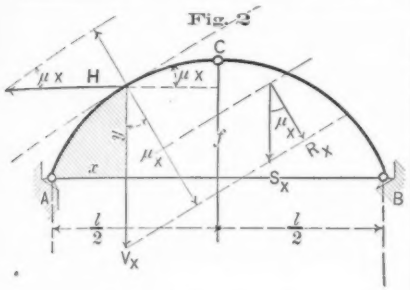
$$M_x = Qx - G_1 (x-g_1) - Hy \quad . \quad . \quad . \quad (5)$$

$$M_x = G_1 g_1 \left\{1 - \frac{2fx+ly}{2fl}\right\} +$$
$$+ G_2 \left\{x - g_2 \frac{2fx+ly}{2fl}\right\} + G_3 (l-g_3) \left\{\frac{2fx-ly}{2fl}\right\} \quad (6)$$

$$V_x = Q - G_1$$

$$R_x = \frac{dM}{ds} = V_x \cos.\ \mu_x - H \sin.\ \mu_x \quad . \quad (7)$$

Fig. 2



$$S_x = \frac{R_x}{\cos.\ \mu_x} = \frac{dM}{dx} = V_x - H \text{ tang. } \mu_x \quad (8)$$

$$S = -G_1 g_1 \left(\frac{1}{l} + \frac{\text{tang. } \mu_x}{2f}\right) + G_2 \left\{1 - g_2 \left(\frac{1}{l} + \frac{\text{tang. } \mu_x}{2f}\right)\right\} + G_3 (l - g_3) \left(\frac{1}{l} - \frac{\text{tang. } \mu_x}{2f}\right) \quad (9)$$

$$S_x = o = \frac{2f}{l} \cdot \frac{G_2(l-g_2) + G_3(l-g_3) - G_1 g_1}{G_1 g_1 + G_2 g_2 + G_3(l-g_3)} - \text{tang. } \mu_x \quad (10)$$

No restriction is made as to the distribution of the loads over the girder. The loads can be distributed in any way over the structure.

According to the *two* distinct kinds of loading, the disquisitions must also be divided into *two* distinct parts:

(1) for loads at rest.
(2) for moving loads.

LOADS AT REST.

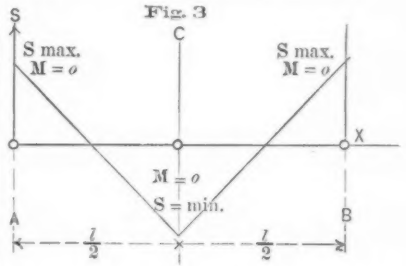
QQ$_1$H.=Reactions of the Abutments. They are constant. The absolute value of H is *increasing* with *decreasing* f or height of the bow.

S=Shearing Forces.

$S_x = \frac{dM}{dx}$, thus the value of S is a max. or min. in the points $M = o$ and it is zero in the points corresponding to the maximum or minimum of M. In equation 9 the first member is always negative, hence S is a maximum in $x = o$ and $x = l$ and a minimum in $x = \frac{l}{2}$, M being necessarily zero in these points in consequence of the joints. S is zero in the points corresponding to $\frac{dM}{dx} = o$.

In using x as abscissa and S_x as ordinate, the law governing the values of S can be graphically represented by a plane curve—the curve of the shearing forces. The form of that curve depends upon the form of the line of thrust and the way of loading the girder. If the line of thrust is a common parabola and the loads are equally distributed over the girder, the curve of the shearing forces are *two straight lines* as represented in Fig. 3.

Fig. 3

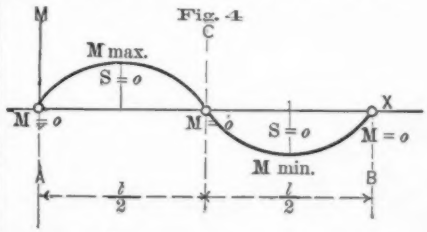


M=Moments.

The moments are zero in $x = o$ $x = \frac{l}{2}$ and $x = l$ in consequence of the joints. In the points corresponding to $\frac{dM}{dx} = o$ the values of M are maximum or minimum. The values of M increase or decrease as long as $S_x = \frac{dM}{dx}$ is positive or negative. In $x = o$ S is a maximum or positive, hence the values of the moments reach always a maximum between $x = o$ and $x = \frac{l}{2}$ and a minimum between $x = \frac{l}{2}$ and $x = l$.

If we use x as abscissa and $M_x = y$ as ordinate, the law governing the values of M will be represented by a plane curve—the curve of the moments.—The form of the curve of the moments also depends upon the form of the line of thrust and

Fig. 4



the mode of loading. If the line of thrust is a common parabola and the loads are equally distributed over the girder, Fig. 4 represents the curve of the moments.

MOVING LOADS.

The value of the external forces now depends upon x as well as upon the positions of the loads on the girder. But in first taking x=constant and only altering the positions of the loads, we obtain the variations of the forces in a point of the girder and especially the positions of the loads corresponding to the maximum and minimum values, which the forces can assume. Considering then the moving of the loads over the girder, as a series of loads at rest, it will finally be easy to apply the above derived laws and especially to define the course of the maximum and minimum values.

QQ_1H=Reactions of the Abutments.

Eqs. 1, 2, and 4 show that they are independent of x and vary only with the positions of the loads. All the members of these equations are positive and increase with G. Hence the values of QQ_1H increase as the loads are covering the girder and reach their maximum with full loaded truss. The absolute value of H moreover *increases* with *decreasing* f or height of the bow.

M=Moments.

In equation 6—x, y being constant—the first member is always positive, as can be easily verified in writing its coefficient:

$$\left(1-\frac{2fx+ly}{2fl}\right)=\frac{l(f-y)+f(l-2x)}{2fl}.$$

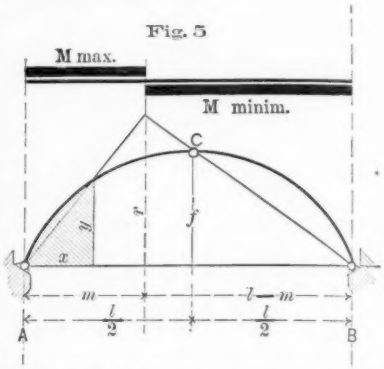
The third member:

$$G_3(l-g_3)\left(\frac{2fx-ly}{2fl}\right)=G_3(l-g_3)\frac{x}{2}\left\{\frac{f}{\frac{l}{2}}-\frac{y}{x}\right\}$$

is always negative, $\frac{f}{\frac{l}{2}}$ being the tangent of the angle of the chord AC or BC and the x axis; $\frac{y}{x}$ the tangent of the angle of Ay and the x axis.

The second member *only* can change its sign, while the loads are running over the girder. The absolute value of M thus depends from the value of this second member, increasing or decreasing as long as it is positive or negative.

Fig. 5



Hence M is a maximum or minimum, when:

$$x-g_3\frac{2fx+ly}{2fl}=o \text{ or}$$

$$g_3=\frac{2fl x}{2fx+ly}=m \quad . \quad . \quad (11)$$

m can easily be graphically constructed. It is the abscissa of the intersection of the chords BC and Ay, Fig. 5. The demonstration follows directly from the figure.

Equation 11 can be put in a more convenient form for use (see Fig. 5.) It is:

$$\frac{y}{x}=\frac{f}{\frac{l}{2}}\left(\frac{l}{m}-1\right) \quad . \quad . \quad . \quad . \quad . \quad (12)$$

or in calling $\frac{y}{x}$=tang. y

$$m=l.\frac{\text{tang. }\mu_f}{\text{tang. }y+\text{tang. }\mu_f} \quad . \quad . \quad (13)$$

For $g_3=m$ the second member of equation (6) becomes zero. This is only possible when G_2 itself is zero. Thus $g_2=m$ represents the limit of G_1 or *that part of the x axis, which must be covered with the rolling load, to make the value of* M *a maximum or minimum.*

Values of g_3 less than m make the second member *positive*,—values greater than m make the second member *negative.*

Hence the value of M is a *maximum* when the x axis is covered from $x=o$ to

$x=m$, with rolling load, a *minimum*, when the x axis is covered from $x=m$ to $x=l$ with moving load, as represented in Fig. 5.

This rule discloses a very remarkable property of the bow girder. It shows that the maximum or minimum of M in any point of the girder depends *only* upon the form of the line of thrust and is independent of the way the loads are distributed over the girder.

In reversing the above given method, it is easy to find for any *load at rest*, that point of the girder, in which M *is a maximum or minimum*. It is sufficient to draw the chord BC and from the intersection with r—the ordinate at the end of the load—a line to A. The intersection of the latter line with the line of thrust is the point x,y in which M is a maximum or minimum according as the load covers the half-bow containing x or not.

If we now suppose for every point in the girder the positions of the rolling load, corresponding to the maximum and minimum of M, constructed in the above way, we shall have a series of loads at rest on which the rules for the latter can be applied.

Thus the maximum or minimum value of M themselves must be zero in $x=o$; $x=\frac{l}{2}$ and $x=l$. They will increase or decrease, with increasing x, as long as $\frac{dM}{dx}=S_x$ is positive or negative. Eq. (9):

$$S_x=-G_1g_1\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)+ \\ +G_2\left(1-g_2\frac{\text{tang. }\mu_x}{2f}\right)+ \\ +G_3(l-g_3)\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right)$$

changes its sign, when

$$\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}=o$$

or in the point x,y corresponding to

$$\text{tang. }\mu_x=\frac{f}{\frac{l}{2}}=\text{tang. }\mu_f \quad . \quad . \quad . \quad . \quad (14)$$

The point x,y, in which the maximum and minimum of the moments become an *absolute maximum and minimum, is thus the point of contact of a tangent to the line of thrust parallel with the chord A C or BC.*

In applying at that point the construction for maximum and minimum of M, it is easy to find the positions of the rolling load corresponding to the *absolute* maximum and minimum values of M in the girder.

This position is also independent of the mode of loading and only depends upon the form of the line of thrust. This fact can be verified in another way:—The absolute maximum and minimum being independent of $G_1G_2G_3$, $\text{tang. }\mu_x=\frac{f}{\frac{l}{2}}$ must be a root of the equation $S=o$, whatever be $G_1G_2G_3$. This is indeed the case, as it is easy to ascertain from equation (10)

$$o=\frac{f}{\frac{l}{2}}\cdot\frac{G_3(l-g_3)+G_2(l-g_2)-G_1g_1}{G_1g_1+G_2g_2+G_3(l-g_3)}- \\ -\text{tang. }\mu_x$$

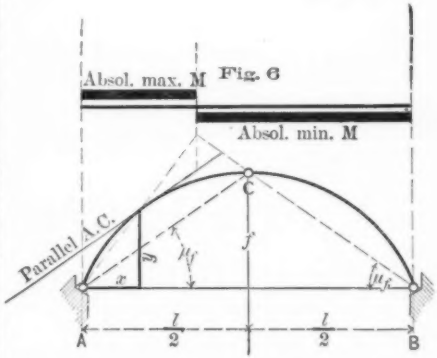


Fig. 6

Fig. 6 shows the graphical construction of the point corresponding to the absolute maximal and minimal values of M.

S=Shearing Forces.

In equation (9) $-x,y$ being constant.—

$$S_x=-G_1g_1\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)+ \\ +G_2\left\{1-g_2\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)\right\}+ \\ +G_3(l-g_3)\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right) \quad (9)$$

the coefficient of the *first* number is always positive.

The coefficient of the *third* member, or

$$\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right)=\frac{1}{2fl}\left\{\frac{f}{\frac{l}{2}}-\text{tang. }\mu_x\right\}$$

is positive or negative according as

$$\text{tang. }\mu_x \lessgtr \frac{f}{\frac{l}{2}}$$

Hence if

$$\text{tang. }\mu_x > \frac{f}{\frac{l}{2}}$$

or for points between $x=o$ and the point corresponding to the absolute maximum of M, that is

$o<x<x$ corresponding abs. max. M.

The *first and third* member of equation (9) is *negative*, and if

$$\text{tang. }\mu_x < \frac{f}{\frac{l}{2}}$$

or for points between the point corresponding to the absolute maximum of M and the crown joint, that is

x corresponding abs. max. $M<x<\frac{l}{2}$

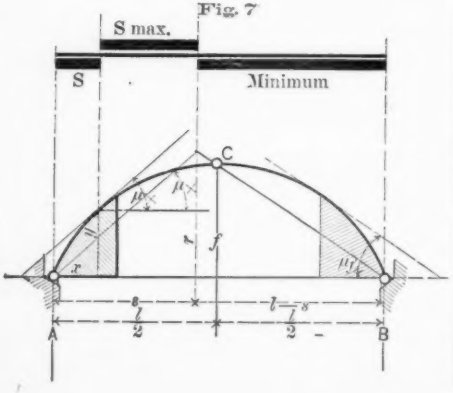
the *first* member is negative and the *third* positive.

The *second* member changes its sign when

$$g_2=\frac{2fl}{2f+l\text{ tang. }\mu_x}=s \quad . \quad . \quad (15)$$

s can be graphically constructed. It is the abscissa of the chord BC and a line from A *parallel with the tangent in point x,y.*

Fig. 7



The demonstration follows directly from the figure.

A more convenient form of s for use is the following:— (see Fig. 7.)

$$\text{tang. }\mu_x=\frac{f}{\frac{l}{2}}\left(\frac{l}{s}-1\right) \quad . \quad . \quad (16)$$

$$s=l.\frac{\text{tang. }\mu_f}{\text{tang. }\mu_x+\text{tang. }\mu_f} \quad . \quad . \quad . \quad (17)$$

s *represents* for reasons shown already by the moments, the limit of G_1, or *that part of the x axis, which must be covered with moving load to make* S *a maximum or a minimum.*

Values of g_2 *less* than s makes the *second* member of equation (9) *positive*, values *greater* than s *negative*. Hence, when

$$\text{I} \quad \text{tang. }\mu_x > \frac{f}{\frac{l}{2}} \text{ or,}$$

$o<x<x$ corresponding abs. max. M.

the *first and third* member of equation (9) being *negative:*

S is a maximum, when the parts of the girder corresponding to G_1 and G_3 are empty, or when the girder is covered with load from $x=x$ to $x=s$, and

S *is a minimum*, when the girder is covered with loads from $x=o$ to $x=x$ and *at the same time* from $x=s$ to $x=l$.

$$\text{II} \quad \text{tang. }\mu_x < \frac{f}{\frac{l}{2}} \text{ or,}$$

x corresponding abs. max. $x<x<\frac{l}{2}$

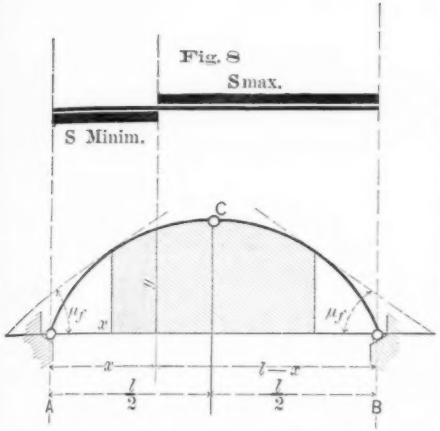
For tang. $\mu_x \lessgtr \frac{f}{\frac{l}{2}}$, s becomes $=\frac{l}{2}$ and the *second* member of equation (9) is *positive*, leaving only the *first* member *negative*; thus:—

S *is a minimum*, when the parts of the girder corresponding to G_2 and G_3 are covered with load, or when the girder is covered from $x=x$ to $x=l$, with rolling load.

S *is a minimum*, when the girder is loaded from $x=o$ to $x=x$.

Fig. 7 shows the graphical construction of the positions of the loads for S max.

and S min., when tang. $\mu_x > \frac{f}{\frac{l}{2}}$ and Fig. 8, the same when tang. $\mu_x < \frac{f}{\frac{l}{2}}$



Generally the loads will be concentrated in certain points of the girder—the panel points—and in constructing the positions of the loads corresponding to the maximum and minimum of M and S the beginning and end of m and s will fall either between two panel points or *coincide* with a panel point itself, and the question arises, how far the loads must in each case cover the girder to produce the maximum or minimum values.

If the end of m or s falls between *two* panel points, the answer presents no difficulty. i and $(i+1)$ be the two points, then evidently m or s will be covered completely with moving load, if the girder is covered from $m=o$ or $s=o$ to the point i (inclusive) and $(l-m)$ or $(l-s)$ will be completely loaded, when the girder is covered from $(i+1)$ including this point to l and it will be easy in each case to find the positions of the moving loads corresponding to a maximum or minimum.

Not so, if the beginning or end of m or s coincides with a panel point itself. It is then impossible *a priori* to decide whether the point must be covered with load or not to produce M or S maximum or minimum, but a decision can be reached in the following way:

I begin with s the value governing the maximum and minimum of S the shearing forces, and we must bear well in mind, that S is *not* acting in *a point*, but as well as tang. μ_x in the *whole panel*.

I.

The Beginning of S Coincides with a Panel Point.

Fig. 9 represents the positions of the rolling load with regard to the panel x.

P=be the sum of all the moving loads acting upon the girder.

a=coefficient expressing the ratio of P to Q_1.

b=that part of P forming with $Q_1 \frac{l}{2f}$ the thrust H.

$\alpha, \beta, \gamma, \Delta$ panel lengths.

p, p_1=loads in different panel points.

Note. P, a, b are of different value for each position of the loads, but as no mistake is possible, no especial letters have been used.

The other letters have the previous significations.

Fig. 9 a=The loads cover the girder from the point $(x-a)$ to any point towards B and again from the point x to the same point towards B. It is:

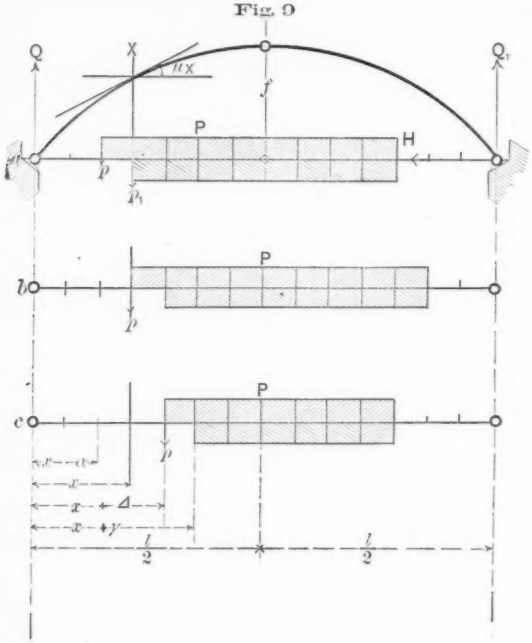
$(x-a)$	(x)
$Q_1^{x-a}=aP.$	$Q_1^{x}=aP-\left(\frac{x-a}{l}\right)p$
$Q^{x-a}=P-Q_1^{x-a}$	$Q^{x}=P-p-Q_1^{x}$
$H^{x-a}=Q_1^{x-a}\frac{l}{2f}-b$	$H^{x}=Q_1^{x}\frac{l}{2f}-b$

AND

$$S_x^{x-a}=P-Q^{x-a}-p-p_1-$$
$$-Q_1^{x-a}\left(\frac{l}{2f}\text{tang. }\mu_x\right)-b\text{ tang. }\mu_x=$$
$$=P-\left\{Q_1^{x-a}\left(1+\frac{l}{2f}\text{tang. }\mu_x\right)+\right.$$
$$\left.+b\text{ tang. }\mu_x+p+p_1\right\}$$

$$S_x^{x}=P-Q_1^{x}-p-p_1-$$
$$-Q_1^{x}\left(\frac{l}{2f}\text{tang. }\mu_x\right)-b\text{ tang. }\mu_x=$$
$$=P-\left\{Q_1^{x}\left(1+\frac{l}{2f}\text{tang. }\mu_x\right)+\right.$$
$$\left.+b\text{ tang. }\mu_x+p+p_1\right\}$$

Fig. 9



HENCE:

$$S_x^{x-a} < S_x^x \text{ when}$$
$$Q_1^{x-a} > Q_1^x \text{ or}$$
$$\frac{x-a}{l} > o$$

Fig. 9 *b*=The loads cover the girder from the point x and again from $(x+\Delta)$. It is:

$$S_x^x < S_x^{x+\Delta} \text{ when:}$$
$$Q_1^x > Q_1^{x+\Delta} \text{ or}$$
$$\frac{x}{l} > o$$

Fig. 9 *c*—The loads cover the girder from the point $(x+\Delta)$ and again from $(x+\gamma)$. It is:

$$S_x^{x+\Delta} < S_x^{x+\gamma} \text{ when:}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{x+\Delta} - 1\right) \text{ or } \ldots (18)$$

$$\frac{\text{tang. } \mu_x}{\frac{l-(x+\Delta)}{(x+\Delta)}} > \frac{f}{\frac{l}{2}} \ldots (19)$$

Recapitulating we find, that *always*

$$S_x^{x-a} < S_x^x < S_x^{x+\Delta} > S_x^{x+\gamma} \ldots (20)$$

The first two conditions result directly from the above equations. The last one:

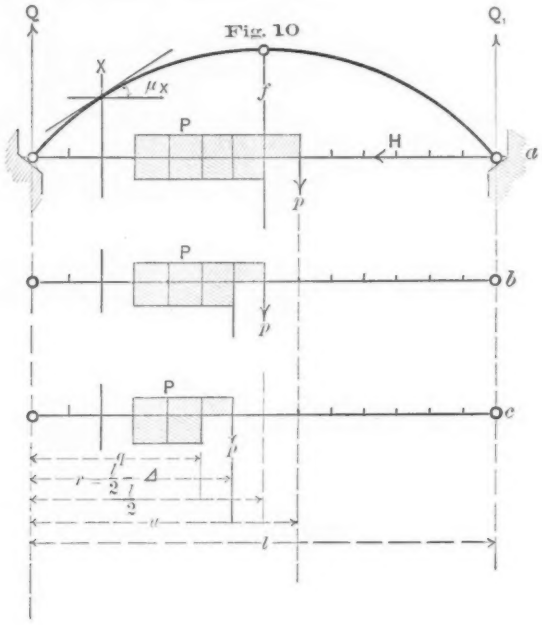
$$S_x^{x+\Delta} > S_x^{x+\gamma}$$

is demonstrated as follows:

Equation 18 shows that tang. μ_x must be $> \frac{f}{\frac{l}{2}}$ to have $S_x^{x+\Delta} < S_x^{x+\gamma}$. This is the case only in panels between $x=o$ and the x corresponding to the abs. maximum or minimum of the moments. Hence it is only necessary to take panels in consideration from $x=o$ to $x=$abs. maximum or minimum of M. But it is evident, that in this part of the line of thrust, tang. μ_x is a max. when x is as small as possible. Thus considering the first panel of the girder we shall have tang. μ_x = max. The value of tang. μ_x in the first panel is:

$$\text{tang. } \mu_x = \frac{y}{x+\Delta}$$

Fig. 10



Using this value in equation 19, we find

$$\frac{y}{l-(x+\Delta)} > \frac{f}{\frac{l}{2}}$$

but as y is always $< f$ and $[l-(x+\Delta)] > \frac{l}{2}$ the above inequality can never be fulfilled and we find equation (20). The equation (20) shows that for S_x *max. in panel* x, the loads *always begin in* $(x+\Delta)$, while for S *min. in panel* x, the loads *always cover the point* x.

II.

The End of S Coincides with a Panel Point.

Fig. 10 represents the positions of the loads with regard to the panel x and the crown joint, in the vicinity of which the end of s falls always.

Fig. 10*a*=The girder is covered from $(x+\Delta)$ to u, and again to $\frac{l}{2}$ with moving loads. It is

u	$\frac{l}{2}$
$Q_1^u = aP$	$Q_1^{\frac{l}{2}} = aP - \frac{u}{l}p$
$Q^u = P - Q_1^u$	$Q^{\frac{l}{2}} = P - p - Q_1^{\frac{l}{2}}$
$H^u = Q_1^u \frac{l}{2f} - p\left(\frac{2u-l}{2f}\right)$	$H^{\frac{l}{2}} = Q_1^{\frac{l}{2}} \cdot \frac{2f}{l}$

and

$$S_x^u = P - \left\{ Q_1^u \left(1 + \frac{l}{2f}\text{tang. } \mu_x\right) - p\left(\frac{2u-l}{2f}\text{tang. } \mu_x\right)\right\}$$

$$S_x^{\frac{l}{2}} = P - \left\{ Q_1^{\frac{l}{2}} \left(1 + \frac{l}{2f}\text{tang. } \mu_x\right) + p\right\}$$

hence,

$$S_x^u < S_x^{\frac{l}{2}} \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}} \quad . \quad . \quad . \quad (21)$$

Fig. 10 *b*=The loads cover the girder

from $(x+\Delta)$ to $\frac{l}{2}$ and again to r. It is

$$S_x^{\frac{l}{2}} < S_x^r \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}} \quad . \quad . \quad . \quad (22)$$

Fig. 10 c=The loads cover the girder from $(x+\Delta)$ to r and again to t. It is—

$$S_x^r < S_x^t \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right) \quad . \quad . \quad . \quad (23)$$

If tang. μ_x is *exactly* $\frac{f}{\frac{l}{2}}$, equations (21) and (22) give—

$$S_x^l = S_x^{l-1} = \ . \ . = S_x^{\frac{l}{2}} = S_x^{r=(\frac{l}{2}-\Delta)}$$

or S maximum is reached in the panel corresponding to tang. $\mu_x = \frac{f}{\frac{l}{2}}$, by loading the girder from $(x+\Delta)$ to *any* point *between* $r=\left(\frac{l}{2}-\Delta\right)$ and l. But, though the maximum of S is reached by any one of the above positions, the strains induced in the members of the girder are not the same for each of the mentioned positions, as will be shown when we shall consider the strains in the members, and with regard to the maximum of the *strains in the members* of the girder, S *is a maximum*, when the girder is loaded from $(x+\Delta)$ to r or to $\left(\frac{l}{2}-\Delta\right)$

Equation (23) shows further that, if

$$\text{tang. } \mu_x \text{ is exactly } \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$$

$$S_x^r = S_x^{(r-\Delta)=t}$$

or that the girder may as well be loaded, say, to r as to $(r-\Delta)$ to obtain S maximum in the panel corresponding to

$$\text{tang. } \mu_x = \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$$

Accordingly, S minimum would begin either with r or with $(r+\Delta)$. But only the last position of the loads will produce S minimum. Hence, though S maximum may be reached, in the above special case, in the mentioned *two* ways, S is a maximum, with regard to the minimum, when the girder is covered to r, and not to $(r-\Delta)$ with load.

Recapitulating, and assuming S to be a *maximum*, we find that the end of s never *extends beyond* $\left(\frac{l}{2}-\Delta\right)$. But s can become *less* than $\left(\frac{l}{2}-\Delta\right)$, according to the form of the line of thrust. The end of s will extend *only* to the following points, or the rolling loads will cover the girder only to the point—

t (inclusive) when tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$

γ (inclusive) when tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{t}-1\right)$

and so-forth.

If the panels are of equal length and $2n$ is their number—the loads may be different in each one—then the loads *cover the girder to the point*, including this point:—

$\left(\frac{l}{2}-2\right)$ when: tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{n+1}{n-1}\right)$. (24)

$\left(\frac{l}{2}-3\right)$ when tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{n+2}{n-2}\right)$. (25)

and so-forth.

For S *minimum*, $(l-s)$ *always* begins with the point *following* the end of s.

The equations (21) to (25) are simply applications of the general equation (16).

The shearing forces in the first panel and the panel containing the crown joints, are:—

$$S_I = \frac{+M^I}{-\Delta} \text{ and}$$

$$S_{\frac{l}{2}} = \frac{M}{+} \frac{\left(\frac{l}{2} - \Delta\right)}{\Delta}$$

and their maximum and minimum depends upon the positions of the loads corresponding to M_I and $M_{\left(\frac{l}{2}-\Delta\right)}$ maximum and minimum.

We now turn to m, the length of the x axis governing the maximum and minimum of the moments.

We shall consider m corresponding to M maximum.

The beginning of m always lies in $x=o$ and nothing special is to be remembered.

The End of m Coincides with a Panel Point.

Equation (13):—

$$m = l \cdot \frac{\text{tang. } \mu_f}{\text{tang. } y + \text{tang. } \mu_f}$$

is exactly the same as equation 17.

$$s = l \cdot \frac{\text{tang. } \mu_f}{\text{tang. } \mu_x + \text{tang. } \mu_f}$$

when we substitute tang. y for tang. μ_x and the deductions from equation (17), will also hold good for equation (13).

Hence, if the end of m coincides with a panel point, say r, it will not alter the absolute value of M maximum, when the girder is covered either to r or to $(r-\Delta)$, but, as by s, with regard to the minimum, M is a maximum, when the girder is loaded to r and not to $(r-\Delta)$. Concerning the *absolute* maximum or minimum of M, it is necessary to bear in mind, that the criterion is bound to tang. μ_x, and that tang. μ_x means not a point, but a whole panel.

In case of M minimum, $(l-m)$ always begins with the next point *following the end of m*.

Before I now proceed to show by an example how plain the application of these rules is in reality, I will recapitulate them in few words.

Moments.

Draw in any point x,y, Ay and BC—see Fig. 5.—The intersection of these lines lies in the panel point m or between m and $m+\Delta$, and it will be in the point x,y:

M *a maximum*, when from o to inclusive point m.

M *a minimum*, when from inclusive point $(m+\Delta)$ to l the girder is covered with loads.

Draw a tangent to the line of thrust *parallel* with the chord AC or BC. The point of contact gives the point of abs. maximum or minimum of M—see Fig. 6.

Shearing Forces.

I. Panels in which tang. $\mu_x > \frac{f}{\frac{l}{2}}$, or $o < x < x_s$ corresponding abs. max. M

Draw BC and from A a line *parallel* with tang. x, y—see Fig. 7.—The intersection of both lines lies in the panel point s or between s and $(s+\Delta)$ and it will be in the panel x.

S *a maximum*, when from inclusive point $(x+\Delta)$ to inclusive point s.

S *a minimum*, when from o to inclusive point x and at the same time from inclusive point $(s+\Delta)$to l the girder is covered with loads.

II. Panels, in which tang. $\mu_x < \frac{f}{\frac{l}{2}}$ or

x correspond. abs. *maximum* $M < x < \frac{l}{2}$

Note.—The tang. μ_x *must be smaller than* $\frac{f}{\frac{l}{2}}$ —see Fig. 8.—

In the panel x, it will be:

S *a maximum*, when from inclusive point $(x+\Delta)$ to l.

S *a minimum*, when from o to inclusive point x the girder is covered with loads.

S_I and $S_{\frac{l}{2}}$ have their maxima and minima with M_I and $M_{(\frac{l}{2}-\Delta)}$ max. or min.

If calculation is preferred, calculate:

1. tang. μ_x in the panels I to $\frac{l}{2}$.

The nearest value of tang. μ_x to $\frac{f}{\frac{l}{2}}$

gives the panel of the absolute max. or min. of M.

2. Calculate m from equation 13 for each panel point and proceed as shown previously.

3. Calculate s from equation 17 and proceed as shown above.

I use both methods together, generally employing the graphical method and the calculation only, where the end of m or s falls so near a panel point, that a sharper definition is wanted.

It is hardly necessary to say, that to the effects of the rolling loads must be added the effect of any load at rest.

EXAMPLE.

Figure 11 represents the line of thrust of a girder of 150′ span. It has 10 panels of 15′ length. f is 30′. The line of thrust is a common parabola. The own weight is assumed to 18,000 lbs. per panel, the rolling load to 45,000 lbs. per panel.

QQ$_1$H.

It is *only necessary* to calculate the reactions of the own weight and for the moving loads, the values corresponding to the successive positions from $x=o$ to $x=\frac{l}{2}$ and for full loaded girder. All other values are found by addition or subtraction as shown, by M minima.

Own weight $=Q^E=Q_1{}^E=81000$ lbs.

Own weight $=H^E=112500$ lbs.

ONLY MOVING LOADS.—$Q_1{}^N Q^N H^N$.

Loaded from point o to point—	$Q_1{}^N$.	Δ_1.	Δ_{11}.	$Q^N+Q_1{}^N$.	Q^N.	H^N.	
0 to 1	$4500=\frac{1}{10}$	9000		45000	40500	11250	$f'H=Q_1\frac{l}{2}$
0 to 2	$13500=\frac{3}{10}$	13500	4500	90000	76500	33750	
0 to 3	$27000=\frac{6}{10}$	18000	4500	135000	108000	67500	
0 to 4	$45000=\frac{10}{10}$	22500	4500	180000	135000	112500	
0 to 5	$67500=\frac{15}{10}$			225000	157500	16875	$H=2.5\,Q_1$.

Full load $=Q^N=Q_1{}^N=202500$ lbs.

Full load $=H^N=281250$ lbs.

In these and the following calculations much time and labor can be saved, in using instead of the panel length, the ratio of this length to the span—here $\frac{1}{10}$. It is then $Q_1{}^{(o-1)}=1\times\frac{p}{10}$, $Q_1{}^{(o-2)}=(1+2)=3\times\frac{p}{10}$, . . . and the calculation of Q_1 for the different positions of the moving loads is reduced to a multiplication of $Q_1{}^{(o-1)}$ with the sum of the panel indices of the loaded panels, as shown above, or

$$\frac{1\,.\,2\,.\,3\,.\,4\,.\,5\,\ldots \text{ panel indices}}{1\quad 3\quad 6\quad 10\quad 15 \quad \text{coefficients}}$$

The correctness of the calculation can moreover be easily verified, the values of Q_1 forming a higher arithmetical seria, which is shown above.

For calculation of H *use equation* 3, for instance:

Full loaded $H^N=$

$$=\frac{202500\times 5-45000\times 10}{2}=281250 \text{ lbs.}$$

MOMENTS.

Use equation 5 *for calculation—*

—See Fig. 11*b*—

Draw BC and Ay in each panel point.

Maxima—

for M_1 and M_2 *loaded from o to point* 3

Q=189,000 lbs. H=180,000 lbs.

for M_3 and M_4 *loaded from o to point* 4

Q=216,000 lbs. H=225,000 lbs.

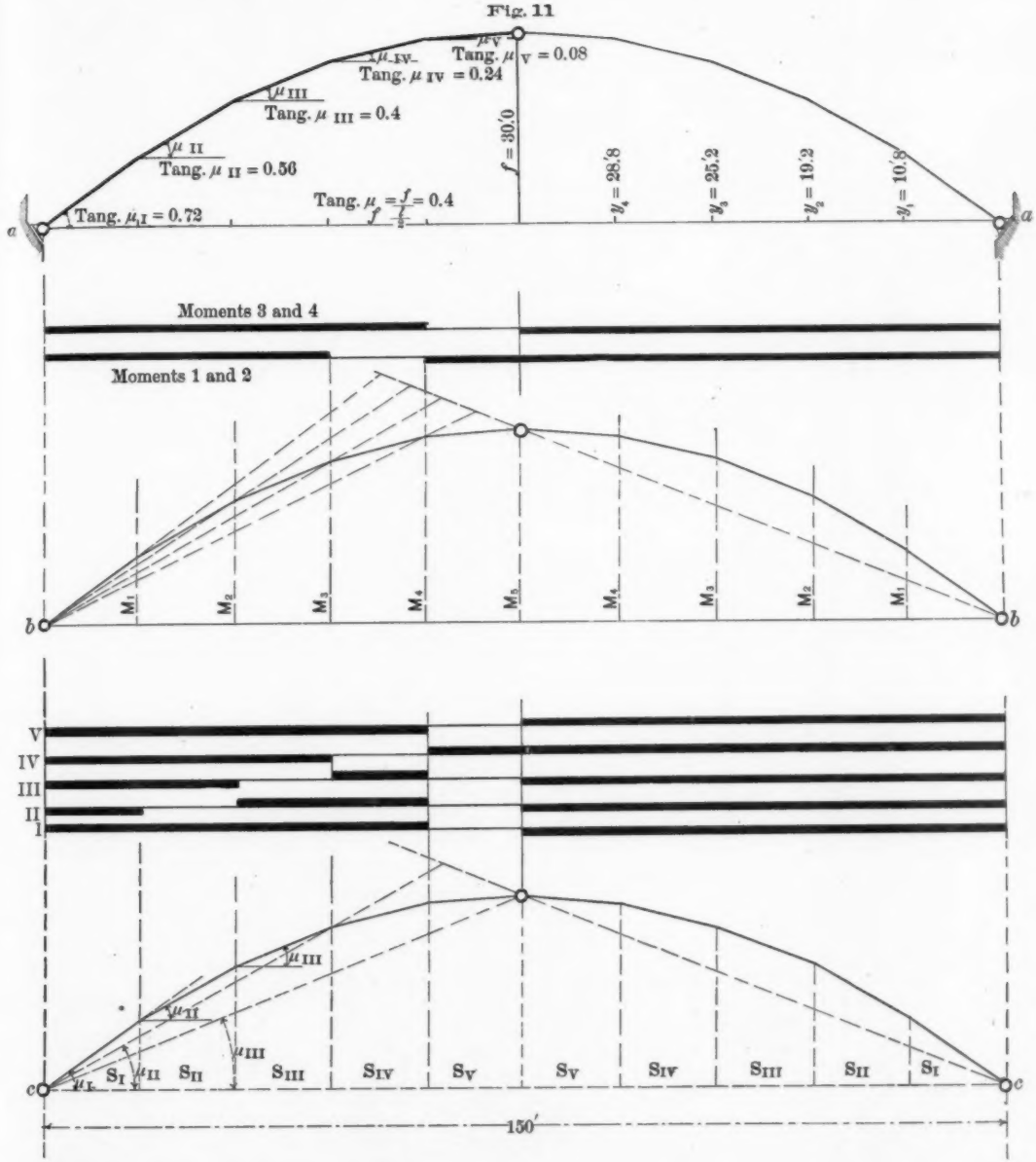
$M_1=+89100$ f. lbs.

$M_2=+(189{,}000\times 15)\times 2-63{,}000\times 15-180{,}000\times 19'2=+1{,}269{,}000$ f. lbs.

$M_3=+1{,}215{,}000$ f. lbs.

$M_4=+810{,}000$ f. lbs.

Fig. 11


Tang. μ V = 0.08
Tang. μ IV = 0.24
Tang. μ III = 0.4
Tang. μ II = 0.56
Tang. μ I = 0.72
Tang. μ = f/(l/2) = 0.4
f = 30.0
y4 = 28.8
y3 = 25.2
y2 = 19.2
y1 = 10.8
a
a
Moments 3 and 4
Moments 1 and 2
b
b
M1
M2
M3
M4
M5
M4
M3
M2
M1
V
IV
III
II
I
μ III
μ II
μ III
μ I
S I
μ II
S II
S III
S IV
S V
S V
S IV
S III
S II
S I
c
c
150'

Minima.

for M_1 and M_2 *loaded from* 4 *to* 10.

	lbs.		lbs.
$Q^{N(0-10)}$	=202,500	$H^{N(0-10)}$	=281,250
$Q^{N(0-3)}$	=108,000	$H^{N(0-3)}$	= 67,500
$Q^{N(4-10)}$	= 94,500	$H^{N(4-10)}$	=213,750
Q^{E}	= 81,000	H^{E}	=112,500
$Q^{(4-10)}$	=175,000	$H^{(4-10)}$	=326,250

for M_3 and M_4 *loaded from* 5 *to* 10,

Q=148,500 lbs. H=281,250 lbs.

M_1 = − 891,000 f. lbs.

M_2 = −1,269,000 f. lbs.

M_3 = −1,215,000 f. lbs.

M_4 = − 810,000 f. lbs.

SHEARING FORCES.

—(see Fig. 11c.)—

Use equation 8 *for calculation—*

Draw BC and the lines *parallel* to the corresponding tangent in each panel.

Maxima.

$$S = \frac{M_1 \text{ max.}}{\Delta} = +59{,}700 \text{ lbs.}$$

S_{ii} loaded 2—4. H=213,750

Q=175,500 H tang. μ_{ii} $=213{,}750 \times 0.56$

p= 18,000 119,700 lbs.

157,500=V_{II}

119,700=H tang. μ_{II}

+37,800 lbs.

S_{iii} loaded 3—4

+27,000 lbs.

S_{iv} loaded 4—10

+43,200 lbs.

S_v loaded 5—10 $= \frac{M_4}{\Delta}$

+54,000 lbs.

Minimum.

$$S_i = -\frac{M_1}{\Delta} = -59{,}400 \text{ lbs.}$$

S_{ii} loaded 0—1 & 5—10 = −37,800 lbs.

S_{iii} loaded 0—2 & 5—10 = −27,000 lbs.

S_{iv} loaded 0—3 = −43,200 lbs.

$$S_v \text{ loaded } 0-4 = \frac{M_4}{\Delta} = -54{,}000 \text{ lbs.}$$

With the knowledge of the external forces, the calculation of the strains in members of the girder is subject to no difficulty, as I will show later.

CO-OPERATION BETWEEN NATIONAL AND STATE GOVERNMENTS IN TOPOGRAPHICAL SURVEYS.

By H. F. WALLING.

Read before the American Society of Civil Engineers at the Buffalo Meeting.

WHILE it is known by civil engineers and other well-informed persons that good topographical surveys are among the necessities of nations for the economical construction of public works and for other useful purposes, this knowledge does not appear to be shared by the people in general, or by their legislators. Our widely extended and comparatively new country, now fairly entered upon its second century of national existence, although in many respects quite as advanced as the older European nations, has, much to its disadvantage, allowed itself to be outstripped by them in this matter.

Among the primary uses to which topographical surveys are put is their guidance in the location of railways and other avenues of internal communication, the abundance and efficiency of which afford to the political economist the most reliable measures of the comparative prosperity of different countries or portions of the same country. The relation between this prosperity and the construction of railways and other public works becomes one of recurring action and reaction, and the effects are accumulative. The public works cause an increase of prosperity which in turn calls for more public works, and so on almost indefinitely. With good topographical maps the best location for a road or railway is readily determined by a careful inspection of the map, and much of the uncertainty

as well as the expense of preliminary surveys is avoided.

In Great Britain, for example, when a new railway is proposed, the best route is first sought by a careful examination of the "Ordnance Maps," upon which exhaustive comparisons of all possible routes can be made as to grades, curves, excavations, embankments, etc., and from the data thus obtained the preferable location can be chosen. The "Parliamentary map" has this selected line laid down upon sheets of the ordnance map, where it can be intelligently considered by a parliamentary committee before legal authority is granted for building the road.

This preliminary map does not usually differ essentially from the more exact map of final location, and the cost of building the road, after so careful a selection of the route, is likely to be as small as possible. Most of the railways of our own country, unfortunately, were constructed without such a valuable preliminary guide and the result has been marked by great waste. It has been estimated by a railway engineer, a friend of the writer, that had the State of Massachusetts been in possession of a good topographical map in 1836, some $20,000,000 would probably have been saved in its public railway expenditures. While it is too late, as he says, to recall the $20,000,000 of unremunerative investments, it is not too late by means of a good survey, to guide private and corporate capital in the economical development hereafter of the various public works which will be demanded by the growing commonwealth.

If a cause be sought for the failure in this country to carry out a measure of obviously wise economy, in which every country in Europe has led the way, with the approbation of all their intelligent citizens, it is to be found, partially at least, in the peculiarities of our form of government, limited to matters of national safety, commerce with foreign nations, management of public property and certain inter-state relations which are regulated under the appropriate departments of the government.

A strong sentiment has prevailed from the outset against any extension of the general government, and up to the present time no direct national legislation has authorized a topographical survey of the country.

In the meantime State legislatures have been slow to see the need of costly surveys and they have been undertaken in but a very few of the States. In some of these, creditable work has been commenced, but in none has it been brought to completion. The State of Massachusetts took the lead in 1829–30 when resolves were passed by the General Court requiring each town in the commonwealth to forward to the Secretary's office an accurate map of its territory on a scale of 100 rods to an inch (nearly 1:20,000). In accordance with subsequent legislation a trigonometrical survey of great excellence was completed in 1838 and the town surveys, after a much needed revision and correction were fitted into the framework of the triangulation. The result was a very good map of the State, the best of its kind indeed that has been made of any of the United States up to the present time. It was drawn upon the scale of two-fifths of an inch to a mile (1:158,400) and engraved on copper. The geographical positions of the sea coast, rivers, streams, lakes, roads, railways, town boundaries, villages, etc., were given with commendable accuracy. The smallness of the scale, however, while permitting the use of the map in one connected sheet, which may conveniently hang on the wall, greatly limits the other uses to which it may be put.

Moreover, the map lacks an important feature, needed to bring it up to the standard of the best of the more modern European maps, and to make it available for engineering requirements, namely, the accurate expression of the vertical relations between the objects represented, in other words their heights above a standard level. Borden's survey determined the heights of most of his primary stations above the level of the sea, and these heights are marked upon the map. But the only other indication of difference of level is by an imperfect system of hachures, which, while attempting to indicate the direction and steepness of slopes, fails to show the differences of level, quantitatively or even qualitatively, except between adjacent areas. The inadequacy of the most perfect system of hachures to intelligently represent quantitative hypsometric relations may be seen

by consulting the best maps constructed in that manner. Among these are some of the official maps, already mentioned, of European countries, which are exceedingly beautiful as pictures, or samples of fine engraving, but fail entirely to convey definite hypsometric information. Practical good sense however seems likely to prevail over that conservative tenacity which opposes even the most obvious reforms and the elaborate hachure systems of Lehman and others are falling into disuse, especially upon maps of large scale and corresponding minuteness of detail.

Lines of equal surface elevation or "*contour lines*," as they are called, if accurately drawn, are much more effective in showing, not only the great general features, but the minute details of height inequalities, and if delicately indicative lights and shadows accompany the contour lines, the general relief of the country may be made to appear at a glance, while the absolute heights can everywhere be ascertained by easy inspection. The intervals of level between these contour lines must be determined in relation to the scale of the map and the amount of elaboration intended.

Although no complete surveys of the scope indicated above have been made by State authorities, . . . (The United States Geological Survey has completed a topographical and geological map of the State of Colorado upon a scale of one-fourth of an inch to a mile with one hundred feet contours) some of the preliminary steps have been taken along the coast regions of the country. The United States Coast and Geodetic Survey, which for many years has been carried on by men of unsurpassed attainments in their special departments of science, has laid the geodetic foundation for a topographical map of the country, so far as the work has been completed, along the two great oceans, the Gulf of Mexico, the lower Mississippi, the Hudson River and Lake Champlain, by a triangulation unsurpassed throughout the world for precision. Moreover, the precedent has been established by Congress, and is not likely to be departed from, of making special appropriations for extending this geodetic triangulation into States where the legislature will provide for geological and topographical surveys. Up to the present time, however, but little alacrity has been displayed on the part of individual States in availing themselves of this proposed co-operation. Special triangulations have only been made in New Hampshire, New Jersey, Pennsylvania, Kentucky, Tennessee and Wisconsin, by the Coast and Geodetic Survey.

In addition to the work of triangulation, an elaborate topographical survey of a narrow strip of land along and adjoining portions of the Atlantic coast has been made under the Coast Survey. The plane table method was employed, the field sheets being generally upon the scale of 1:10,000 or nearly that of the later maps of the British Ordnance Survey, namely, six inches to a mile. Upon these sheets contour lines are marked with vertical intervals, usually of twenty feet. The details of topography are otherwise shown with great minuteness. A series of sheets of this kind for the whole country would be of incalculable value for engineering and other purposes.

They would, however, still lack an important feature which gives great value to the Ordnance and some other European maps, namely, the delineation of property lines. The Coast Survey maps show fences and other lines of enclosure, but without regard to ownership. As all land surveyors know, the determination of the lines of actual ownership is a work involving peculiar difficulties, arising mainly from the imperfection and conflicting nature of the various kinds of evidence depended upon.

In Great Britain the Ordnance Surveyors are required to serve regular formal notices upon the land owners or their legal representatives, who are notified to be present at the time of the survey for the purpose of pointing out their lines and presenting the confirmatory evidence in their possession. By this means an official character is given to these boundary surveys which has the general subsequent effect of preventing much disastrous litigation which might otherwise arise. The addition of property lines, with adequate descriptions, constituting what are called "*cadastral maps*," not only serves to strengthen and perfect titles, but renders the maps useful for the equitable assessment of taxes, the adjustment of betterments for public

improvements, etc. The use of cadastral maps has already extended to Canada and to some of the larger American cities and towns.

Since, with its present organization and yearly appropriations, it would require many centuries to complete a survey of the entire country, in the style of the narrow strip above mentioned, even without the cadastral element, the work of the Coast and Geodetic Survey is at present limited to the completion of its series of admirable coast charts and the valuable scientific investigations connected therewith, and to the extension of the geodetic work across the continent from ocean to ocean. This grand triangulation, when completed, will afford an admirable basis for topographical maps made by such special organizations as the various needs of different sections may indicate.

The position of the Atlantic States gives them the advantage of the primary triangulation of the Coast Survey which already extends across the New England States to the Hudson River and Lake Champlain, and along the Blue Ridge and adjacent mountains of the Appalachian chain in Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Alabama. In addition to this general primary or geodetic triangulation the Coast Survey organization is well adapted to supply the secondary triangulation by which the geographical positions of many convenient points intermediate between the primary stations would be given for the convenience of the surveyors who would follow and work up the minute details of topography. Government co-operation to this extent with State surveys, topographical and geological, has already been established in the States of New Hampshire, Pennsylvania, and New Jersey, and will doubtless be called for in all the States successively as the advantages of topographical surveys become apparent to them.

In the meantime another government organization has undertaken the preparation of topographical maps and is prepared to co-operate with States in this work. The United States Geological Survey, originally organized to investigate the geological relations and resources of the national domain in the western territories, has been authorized to extend its researches over the entire country. The desirability of this is apparent when we consider that geological formations are independent of civil boundaries, and that their relations can be best ascertained by tracing them from State to State over the widest accessible areas.

The absence of good topographical maps presents at the outset a formidable difficulty in the way of geological investigation. Geology and topography are intimately related and, to a considerable extent, dependent upon each other. The officers of the Geological Survey are accordingly compelled to supply the deficiency by constructing maps for themselves as the work goes on. For this purpose a "Division of Geography" has been organized, with an accomplished and experienced chief, under whose direction skilled topographers are assigned to the sections where immediate geological work is intended.

The immediate benefits which will accrue from this undertaking even while in progress are so apparent that, having been fairly inaugurated, it is not likely to be abandoned in a progressive country like ours.

Its magnitude, however, assumes almost overwhelming proportions and the conditions under which it must be exercised are such as to call into exercise, judgment, skill and executive ability of a very high order. While the results must be reliable and accurate, rapidity of execution and economy in expenditure are also indispensable.

The first consideration which presents itself is that different parts of the country will need to be surveyed with different degrees of elaboration on account of the great variations in existing conditions. The older and more fertile portions of the country are already occupied by a dense population, much of which is concentrated in and about numerous large cities, towns and villages. An intricate network of roads and railways affords easy inter-communication between all parts of this inhabited region. On the other hand a large part of the country remains in the aboriginal condition of nearly unbroken solitude. Portions of this unsettled country are more or less susceptible of cultivation, or possess mineral or other industrial resources. These portions will eventually partake of the

general increase in the population of the country and its accompanying development of cities, towns, roads and railways. But there will always remain vast regions made up of wild mountain peaks, ridges, with steep rock-bestrewn slopes, precipitous cliffs, deep gorges, broad stretches of bare rock cut by impassable cañons and great tracts of arid and uninhabitable territory.

A high degree of precision in the rendering of minute details cannot be obtained in these wildernesses, except at a cost of labor greatly disproportionate to the uses which can be made of the maps. If the more general topographical features, only, are accurately shown, all useful purposes will be subserved, and the scale may be much smaller than when the details are elaborated with greater precision.

The scale adopted for maps which have been made under the U. S. Geological Survey, is one-fourth of an inch to a mile, and this will doubtless prove adequate for the record of such geological characteristics as can be ascertained for many years. In some of the mining districts, however, where the presence of rich metallic veins has caused a rapid settlement of the locality by eager searchers for wealth, the details of geological information developed by the miners are found to require special maps on a large scale for their proper display.

The question whether there shall be co-operation between State authorities and the U. S. Geological Survey in the construction of topographical maps has an important bearing in determining the scales which may be adopted by the Geological Survey, for the maps of those sections of the country included under State jurisdictions. Such a co-operation, for example has been proposed for the State of Massachusetts and is now under consideration by its legislature. The Geological Survey needs as a basis for its representation of the geological formations, a map upon which the outcrops and other indications may be accurately located by the geologist, both in their horizontal and vertical relations. The more numerous the recognizable points of reference, and the narrower the spaces between them, the greater will be the degree of precision with which he will be able to record his researches, and the more valuable will the record become. But the limited sum appropriated by Congress for the Geological Survey must be divided between the geological and the topographical work, which are to go on nearly simultaneously, the topographers keeping a little in advance of the geologists. The work of the "Division of Geography," though preceding it in the order of time, is subsidiary to the regular geological work of the survey, and is likely to receive a smaller share of the entire appropriation.

In the absence of co-operation by any State with the United States Geological Survey, in preparing the topographical map of that State, this limitation of means will, of course, appear in the final result.

In Massachusetts the scale of the existing State map is, as stated above, two-fifths of an inch to a mile. The U. S. Geological Survey has already done some preliminary work there, with a view of constructing a map with contour lines, on a scale of half an inch to a mile. It is evident, however, that this scale, about one-half that of the first British Ordnance Survey, would, like that, prove inadequate to serve the engineering and other purposes for which maps are needed by States and municipalities. In 1824 while the work of the Ordnance Survey was in progress in England, it was found necessary by the government to make a general property valuation of all Ireland. For this purpose the survey of that island was made on the scale of six inches to a mile, or 1:10,560 and the boundaries of farms, etc., were all carefully surveyed and delineated in addition to the other details of topography. When the survey of Ireland was finished in 1840 the maps were found so useful for other uses that the same scale was adopted for a re-survey of the kingdom, and, though the work was from time to time obstructed by the lack of adequate parliamentary appropriations, its real value has been so apparent that it has not been discontinued, and it must now be near completion.

The difference between the scale of the present official map of Massachusetts, two-fifths of an inch to a mile, and that of the larger Ordnance maps of Great Britain, six inches to a mile is, in linear dimensions, as one to fifteen; in area, as 1 to 225. That is, it would take 225 times as many sheets of the same size to show the whole of Massachusetts, upon

the scale of the Ordnance map, as upon Borden's map. The cost of adopting the Ordnance scale is evidently too great to be undertaken at present, and for the general map of the State, a publication scale of 1:50,000, or about one and a quarter inches to a mile is probably as large as would be required for most of the purposes for which it would be used, including preliminary investigations for railway locations, for water supply of cities, etc. This scale has been recommended by international scientific conventions in Europe as the most practical and convenient for general uses. A convenient size for single sheets would cover ten minutes of latitude and twenty minutes of longitude, making the size of the sheet, exclusive of margin, about fourteen and a half by twenty-one and a half inches. About sixty-five sheets of this size would be required to cover the whole State including a number of fractional sheets along the sea coast.

The expense of preparing maps on a sufficient scale to serve for cadastral and other municipal purposes should, under our system of independent municipal sovereignties, be borne by each municipality whenever its want becomes felt. A number of cities and towns in this and some of the adjacent States have already provided themselves with such maps, and it is probable that others might have them provided in connection with the proposed survey, by defraying the additional expense of increasing the scale, giving property lines, areas of lots, etc.

The cost of the general survey of the State, of which the above general outline has been given has been estimated by the Geological Survey at about $80,000 to be distributed over four years. Of this expense the Geological Survey proposes to defray one-half. It is not easy to ascertain in advance the exact cost, which will depend upon the minuteness of the details and the degree of precision with which they are represented.

Some of these details, for example, consist of the outlines of woodland, of pastures, the minute meanderings of streams, fences, stone-walls, buildings, etc.

Another element of variation in expense is the differences of level between adjacent contour lines. For the scale of 1:50,000 proposed, twenty-five feet might be adopted for the intervals between contours over the more level portions of the State, and fifty feet for those among the mountainous regions.

For comparison of the work proposed with the surveys of Europe, the following concise account of some of them has been taken from an interesting paper in the *North American Review* for July, 1875, on "Geographical Surveys," by Professor J. D. Whitney, who has given careful attention to this subject:

"Let us begin with Great Britain, which, including Ireland, has an area of nearly 111,000 square miles, and where the topographical survey has been going on since about 1784. The scientific work is partly performed by officers of the Royal Engineer Corps (382 military, including officers, and 1,446 civil assistants were on the Ordnance Survey staff in the year 1872), and it is officially known as the "Ordnance Survey." Its total cost from 1791 to the end of 1864, including the military pay of the men employed, was £2,991,624, and may be estimated up to the present time about £4,200,000. The scales adopted are numerous, and in case of some cities are as large as five and even ten feet to the mile. The principal published maps, however, are on two scales, one of six inches and the other of one inch to the mile (1:10,560 and 1:63,360). Of England, the map on the one-inch scale was begun in 1784 and finished in 1869; but the projection employed in it was defective, and it is in other respects not up to the present requirements of the country, hence it is now in process of working over and re-publication. Of the area surveyed on the six-inch scale, 24,877 square miles had been completed in England and Wales, and 27,829 in Scotland, up to the end of 1873, Ireland, on the same scale was entirely finished in 1845, and all the sheets, 205 in number, published without, and about half with, the hill-shading. Besides the maps on the six-inch and the one-inch scales, plans are furnished of any district as called for on the scale of 1:2,500 (about 25 inches to the mile), made by photo-zincography: but these are not necessarily engraved or published. The map of London is on a scale of 1:1,000, and is comprised in 821 sheets. The various publications of the Ordnance Survey are sold in single sheets as wanted at very

moderate prices; but so great as to their number, that the cost of a complete set, as far as published amounts to over £3,000. A great deal of work is prepared for the use of the government on very large scales, but it is chiefly the six-inch and one-inch maps which are of importance to the general public. At the present rate of progress it will require about ten years to complete the survey.

In Belgium the scale adopted is 1:20,000, the area of the country being about 10,000 square miles, 450 sheets will be required, of which 137 were published up to the end of 1873; the contour lines are drawn at distances of one meter, every fifth one being indicated by a heavier line; the sheets are lithographed and printed in colors, the rivers and lakes being in blue, the lettering and roads in black, the meadows and forests in different shades of green, the buildings in brick-red, and the gardens in carmine.

In Prussia, since 1849, new and more perfect methods have been introduced into the topographical surveys; the plane-table sheets are now published on a scale of 1:25,000, and with contour lines with distances of five, twelve and a half or twenty-five feet according to the nature of the country. The publication of the plane-table sheets was commenced in 1868, and in 1873 120 had been issued. There has also been, since 1841, a general map in process of publication, on a scale of 1:100,000, which will be comprised in some 400 sheets, of which nearly all are issued. These are engraved on copper and have the topography, or hill-shading indicated according to Lehman's system as modified by General Müffling.

In Baden, the new map was commenced in 1874, on a scale of 1:25,000, and with contour lines at ten meters distance. The work is mainly a revision and correction of older surveys and is expected to occupy six years at a cost of about 80,000 florins.

In Saxony, the original survey was commenced in 1780, and completed in 1806 on a scale of 1:12,000, the area of the kingdom being 5,600 square miles. A topographical map was issued in the years 1837–1860 in 22 sheets and on a scale of 1:57,600. A new map was determined on in 1860, and it was completed in ten years; there are two editions of this, one with the line-work only and the other with the hill-shading.

Having now shown what is doing in some of those European states which are, comparatively speaking, rich, densely inhabited, and with moderate areas of territory, let us turn to the consideration of some countries which have only a thinly scattered population and a large area. Russia, for instance, with its enormous territory, just about twice the size of that of the United States, Alaska included, has been for many years actively engaged in prosecuting geographical surveys. The map of Russia in Europe, embracing about 2,100,000 square miles has been under way since 1857, and will be embraced in about 700 sheets, of which 454 had been published in 1872. This is on a scale of 1:126,000. The military map of Poland is on the same scale and is embraced in 57 sheets, all of which are published. Special maps of the Caucasus have also been completed and, recently, a map of Central Asia.

Norway has an area of 123,300 square miles, and a population about that of Massachusetts; that is, our own State is eighteen times more densely populated than Norway. But this comparatively poor country has set itself on having a good topographical map on a scale of 1:100,000, and which will occupy over 200 sheets. Those which have already appeared have been highly praised for their execution by competent judges; they are printed in chromo-lithography, like those of Belgium.

Sweden also, very similar to Norway in respect to area and density of population, has her topographical maps on the same scale (1:100,000) and the work is already nearly half completed, the first sheet having been published in 1860.

The following information in regard to the surveys of other European states, in addition to those enumerated by Professor Whitney, has been gathered from reliable sources. (See *Geographical Magazine*, Vol. IV., p. 125 *et. seq.*)

Saxony, in addition to the maps before mentioned, has undertaken a new survey on a scale of 1:25,000 to be comprised in 156 sheets, the elevations to be shown by contours, with crayon-shading to bring out the relief.

Bavaria, having in 1868 completed her map in 112 sheets on the scale of 1:50,000,

SCALES OF TOPOGRAPHICAL SURVEYS.

EXPLANATION.—Each square is drawn with sides of one-half mile on the scale designated, which is indicated both in the natural way by giving the proportion to nature without regard to any standard of measurement, and by "Inches to a Mile."

U. S. GEOLOGICAL SURVEY.
(Maps of Western Territories.)

$\frac{1}{31{,}680}$, or $\frac{1}{2}$ Inch=1 Mile.

MASSACHUSETTS.
(Borden's Map, 1884.)

$\frac{1}{15{,}840}$, or $\frac{3}{8}$ Inch=1 Mile.

HUNGARY.

$\frac{1}{144{,}000}$, or 0.44 Inch=1 Mile.

RUSSIA.

$\frac{1}{126{,}720}$, or $\frac{1}{2}$ Inch=1 Mile.

PRUSSIA (General Map).
NORWAY.
SWEDEN.
PORTUGAL.

$\frac{1}{100{,}000}$, or 0.636 Inch=1 Mile.

FRANCE (General Map).
U. S. COAST SURVEY,
(Published Coast Charts.)

$\frac{1}{80{,}000}$, or 0.792 Inch=1 Mile.

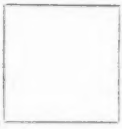
AUSTRIA
(General Map).

$\frac{1}{76{,}000}$, or 0.8448 Inch=1 Mile.

GREAT BRITAIN
(First Ordnance Survey.)

$\frac{1}{63{,}360}$, or 1 Inch=1 Mile.

NETHERLANDS.
SWITZERLAND (Mountains).
ITALY.
BAVARIA.
WURTEMBURG.
SPAIN.
Proposed Survey of Mass. (Public'n Scale).



$\frac{1}{50{,}000}$, or 1.2672 Inch=1 Mile.

DENMARK.

$\frac{1}{40{,}000}$, or 1.584 Inch=1 Mile.

PROPOSED SURVEY OF MASS. (Field Sheets.)

$\frac{1}{20000}$
or
2.112 Inch.=1 Mile.

PRUSSIA (Field Sheets)
AUSTRIA "
BAVARIA "
ITALIAN STATES.
SWITZERLAND.
SAXONY.
BADEN.

$\frac{1}{25000}$
or
2.5344 Inch.=1 Mile.

BELGIUM.

ITALIAN STATES (Field Sheets).

FRANCE (Department of Seine).

$\frac{1}{30000}$
or
3.168 Inch.=1 Mile.

INNER SQUARE.

$\frac{1}{10560}$, or 6 Inch.=1 Mile.

ORDNANCE SURVEY OF GREAT BRITAIN.

OUTER SQUARE.

$\frac{1}{10000}$, or 6.336 Inch.=1 Mile.

U. S. COAST SURVEY. (Field Sheets.)

has a new edition in progress. Also publishes photo-lithographic copies of the original plane-table sheets, scale 1:25,000.

Wurtemburg has also a map on the scale of 1:50,000, of which a new edition is in progress.

Austria commenced in 1874 a new map comprising 715 sheets, scale 1:75,000, each sheet including 15′ of latitude and 30′ of longitude. The drawings for this map are transferred to copper and the engraved plate is produced by etching. 151 sheets had been published up to 1878. The survey scale is 1:25,000. This map must now be near completion. Hungary covers 198 sheets on a scale of 1:144,000. The environs of Vienna are shown in two maps on the scale of 1:12,500 and 1:25,000. Hills are shown by contours having intervals of ten meters, with crayon-shading, roads are printed in red, forests tinted in delicate green, and the outlines and lettering in black.

Switzerland has a fine large map beautifully engraved in hachure, but is preparing a new survey in 546 sheets, the scale of the cultivated districts being 1:25,000, while the barren mountain regions are shown on the scale of 1:50,000.

The Netherlands issues a new edition of her map on the scale of 1:50,000.

Denmark has a survey in progress, scale 1:40,000.

The great map of France is on the scale of 1:80,000 and is comprised in 267 sheets. Contour lines are printed in brown, and water in blue. Some of the departments are being published on the scale of 1:20,000.

Italy is being mapped on the scale of 1:50,000. The field sheets are on the scale of 1:25,000.

Spain, with a good general map by Coelho, has been engaged since 1858 on a new survey, scale 1:50,000. Each sheet covers 10′ of latitude and 20′ of longitude. The intervals between contours are 10 and 20 meters. Rather slow progress is being made.

Portugal commenced a map in 1856 on the scale of 1:100,000. The earlier published sheets showed the hills in hachures, but of late the contour system with intervals of 25 meters has been adopted.

The accompanying diagram is intended to show the proportions of the different scales which have been mentioned. Each square is drawn to the scale designated, with its sides half a mile in length.

A brief summary of the entire mode of procedure to be used in constructing the proposed topographical maps by the U. S. Geological Survey in Massachusetts will show the high degree of accuracy that may be expected from it.

The first operation, which has already been completed by the State Trigonometrical Survey and by the United States Coast and Geodetic Survey, was the primary triangulation of the entire State by which the positions of about one hundred points in different parts of the State were determined with the highest degree of precision attainable by human instruments and methods. This precision has been tested by measuring two base lines, hundreds of miles apart, and comparing the length of one, obtained by computation from the other along a series of intervening triangles, with its actual measured length. In this way the Coast and Geodetic Survey proved that the amount of possible error in their determinations of the relative positions of the intervening points, is limited to less than one two-hundred-and-fifty-thousandth part of the actual distances, or less than one foot in fifty miles.

The next step in the work is the secondary triangulation by which numerous points intermediate between the primary stations are located to serve as reference points for the subsequent survey of the topography in detail. It is advantageous to have as many as possible of these reference points and they should be well defined and conspicuous objects. Borden fixed the positions of some 350 secondary objects, consisting mostly of churches and other public buildings. But the forty years which have since elapsed have brought many changes. Many of the churches, etc., have been razed, burnt or removed and other points of reference have become obliterated.

The Coast and Geodetic Survey also located many secondary and tertiary points and made use of them in preparing the topographical sheets of the narrow strip along the coast, mentioned above. This strip is, however, wider than usual along parts of the Massachusetts coast. It includes the islands of Martha's Vineyard and Nantucket and nearly all of Cape Cod.

The area over which the topography is thus completed is about 800 square miles, which for the proposed co-operation scheme only needs revision for the purpose of adding town and city boundaries, new roads, railways, mill-ponds, etc., with some changes in the outlines of the coast near Cape Cod, caused by the inroads of the ocean waves.

The remaining area of the State, about 7,000 square miles, will need to have a great many secondary stations fixed by preliminary triangulation to prepare for the delineation of the topographical details. This secondary triangulation does not require the amount of refinement which is requisite for the geodetic or primary triangulation, upon which depends the precision of work hundreds of miles away, and the final determination of the form and size of the earth. Having the primary stations to work from, the precision obtainable, even with the ordinary instruments used by civil engineers, is quite sufficient for cartographical purposes, since it exceeds the capabilities of graphic delineation.

The plane table, an instrument which enables the surveyor to construct his map in the field by the graphic method, has been used by the Coast Survey from the commencement of its topographical work, and all its topographers are trained in its use. For cartographical purposes it has many advantages, as it dispenses with much of the work of ordinary surveying, the measurements of distances and angles, the keeping of field notes and subsequent plotting of the notes by protractor and scale. By this method after the trigonometrical points have been projected upon the field sheets, other points are marked by intersections of lines drawn by a ruler with an attached telescope, called an *alidade*, which being placed over the point occupied is directed toward any point to be located. When another known point is occupied and a second line drawn towards the desired point, the plane table being in both cases properly "*oriented*," that is, the direction between any pair of points upon it being made parallel to that of the corresponding pair upon the ground, the intersection of the two lines gives the position of the new point upon the map. Moreover, when the plane table is placed over an undetermined point from which three determined points are visible, its position can be ascertained and marked upon the map by a graphic solution of the three-point problem. In addition to these and other graphic methods of solving trigonometrical problems, the features of the ground in the immediate vicinity of the point occupied may be conveniently represented by the aid of stadia or telemeter rods carried by assistants over the ground from point to point. The distance of the rod from the plane table is seen by inspection in the telescope of the alidade and corresponds to the number of divisions, conspicuously painted upon the telemeter, which are intercepted between two horizontal hair lines in the telescope. Of course the direction to the point where the rod is held is given at once on the map by the ruler of the alidade.

The more numerous the points instrumentally determined, the more accurate should be the final result, as between these points, the lines of contours, streams, etc. must at last be sketched in by the aid of the eye which requires careful training for the proper estimation of the proper proportions in nature and for their reproduction in the sketch. Our philosopher-poet, Emerson, says "a work of art is an abstract or epitome of the world. It is the result or expression of nature in miniature."

The converse of this is also true, and topography, though based upon exact science, is entitled to rank among the fine arts. The most skillful topographer is he who is able to give the real expression which pervades the face of nature corresponding to that which is seen in the human countenance, an expression which is the revelation of the forces which have acted to produce it.

The geologist studies the active agents of natural forces, the ocean waves and tides, the winds, rains and running streams, and ponderous creeping glaciers; the slow action of gravity, incessantly carrying down the great basins of deposit which would otherwise gradually become filled up, and raising the places which are lightened by the robberies of the wearing waters, keeping up thereby an underground movement, which with the surface movement, constitutes a complete *circulation of materials*; and the occasionally sudden action of gravity, when the

strained sheets of rock finally give way, and move to new levels of temporary equilibrium with accompanying earthquakes and lava flows. He sees the sculpturing effects of the super terranean agents which are continually carving the face of the earth into forms which reveal its past history even from those inconceivably remote ages when its living inhabitants, its plants and animals, were strangely different from those of the present day.

These studies enable him to detect incongruities in the work of an unskilled topographer whose representations of the surface conflict with the true character of the underlying rocks carrying the characteristic marks of the subterranean agents which have bent and torn them, while lifting them to be shaped into grand and beautiful contours of the ever varying landscape.

The use of the plane table may in some respects be compared to the work of the artist who plants his easel in the field where he can compare his picture with nature as it progresses. It has been adopted by the U. S. Geological Survey, whose topographers find it especially well adapted for mountain topography. The accuracy of the method is only limited by the conditions of graphic representation, and if the proposed survey of Massachusetts is made, this will be the method employed.

If all the sheets of the map on the proposed scale of 1:50,000 are joined together when completed to make one continuous map it will extend about twenty feet from east to west. Such a sheet would be too unwieldy for ordinary uses, most of which could be conveniently made with the separate sheets. It would be easy, however, to join any required number together, making continuous maps of entire counties, of drainage areas and of preliminary surveys for railways, for water supply and for sewerage of cities, etc.

For schools and academies, a small number of sheets covering the surrounding region, joined together and hung upon the school-room wall, would enable pupils to study the physical geography of their own immediate neighborhood, and to cultivate habits of exactness in observation and comparison.

Plaster models of parts or the whole of the State could be made for museums, colleges, etc., with little difficulty, showing in miniature all the inequalities of the surface in their true proportions.

The exact areas, relative positions and differences in heights, of drainage basins, lakes, ponds, swamps and meadows could be found, for sanitary and other purposes by inspection of the maps.

To enumerate, indeed, all the useful purposes of such a series of accurate maps would be difficult if not impossible.

The question now presented to the legislature of Massachusetts is whether the State, by co-operation with a trained organization of high character, will secure a survey of this nature at less than half the cost which would be incurred in a separate undertaking.

On the other hand in case the State declines to co-operate, the Geographical Division of the U. S. Geological Survey expects to prepare a map at a cost of about $20,000. The result will be a map having a greater scientific value than the present map, but falling far short of fulfilling the engineering and other State purposes which are attainable by the proposed plan of co-operation.

Is it not to be feared that this course would have the effect of postponing the more elaborate survey until the false economy of the delay should have become evident, even to the most unappreciative minds by repeated wasteful expenditures that might have been avoided by improving the present opportunity?

Viewed with regard to the welfare of the whole country it would seem that a scheme of national co-operation such as has been outlined above, is worthy of the careful consideration of each of the several commonwealths. The amount of detail for each State and the consequent cost of the work having been adjusted to its special needs, the conduct of the survey under a skilled national organization would be likely to accomplish far more satisfactory results than if State surveys were independently organized.

THE great tower of Norwich Cathedral is in a state which is causing anxiety, and, like the Peterborough Cathedral, may have to undergo important and expensive operations. The wall of the tower near the top is weakened by the introduction of a passage and open arcade, and the weight of the spire above is causing settlements in that part. It may, however, be possible to put in the saving stitch.

ON A PRACTICAL SOLUTION OF THE PERFECT SCREW PROBLEM.*

By Prof. WILLIAM A. ROGERS.

From "English Mechanic and World of Science."

Prof. Rogers said that at the outset it was essential that the term "perfect screw" should be defined. Perfect is a relative term. A piece of mechanism may be termed perfect when it meets all the requirements of the purpose for which it was constructed. After describing the errors to which screws are subject as being an error in the total length, the pitch of the screw for even revolutions not being uniform, and the fact that there may be a gradual increase of pitch up to a certain point, and then a diminution until the amount of decrease is equal to the previous amount of increase, he detailed the most important failures to make satisfactorily perfect screws, and continued:—An order was received from Prof. Wm. A. Anthony for the construction of a dividing engine for the Physical Department of Cornell University. Upon accepting the order, a shop was fitted up in Boston with tools of the best quality, chiefly from the establishment of Pratt and Whitney, and Mr. Ballou undertook the construction of the engine, mainly from his own designs, and of the screw which is its essential part. The completed machine was shipped in just 35 weeks after the actual commencement of the work; and the screw, which will be presently discussed, was cut and ground in 27 hours from the time the first tracing of a thread was made. It was at that time practically perfect for about 20 inches, and nearly as perfect as it afterwards became by the process of grinding adopted. Notwithstanding the fact that the work was done upon a common lathe in which the errors of the leading screw were enormously large, the result showed that the method employed was based upon correct mechanical principles, and was entirely feasible.

This method can be described in a very few words.

Let the reader hold clearly in mind the following. There are:

1. an ordinary lathe, the ways of which have been made as nearly straight as possible.

2. A shaft between dead centers which maintains a cylindrical form during every revolution and every part of a revolution.

3. A microscope provided with Tolles' opaque illuminator for viewing opaque objects, attached to the carriage moved by the leading screw of the lathe.

4. A graduated bar mounted independently of the carriage, with subdivisions which are multiples of single threads of the leading screw.

5. A slide moving parallel with the leading screw, by means of a very short and firmly mounted micrometer screw of comparatively large diameter and attached firmly to the carriage. The tool-post is secured firmly to the secondary slide.

6. A mechanical means of determining when the leading screw has made a complete revolution.

The method of proceeding was as follows:—The graduated bar having been leveled up and set parallel to the axis of the screw to be cut, the micrometer of the microscope was set upon the initial line. The lathe was then started with the leading screw "in feed." After the screw had made, for example, nearly ten revolutions, the lathe was stopped and the remainder of the even revolution was completed by hand manipulation. The deviation of the micrometer line from the corresponding graduation upon the bar was then measured in terms on the screw head of the secondary micrometer screw. In this way the errors of the leading screw with respect to the graduations of the standard bar were determined and written down upon a strip of paper pasted to the vertical face of the bar. The carriage was then started again with the cutting tool in operation, and by means of a rough pointer, the micrometer screw

* A paper read at a recent meeting of the American Society of Mechanical Engineers.

working the secondary slide was fed either forward or backward, in accordance with the corrections before determined. Hence, when the even revolution was completed, it would be found that the line of the bar would be nearly under the cross wire of the microscope. This operation was kept up until the screw was finished.

At the completion of the operation of cutting, it was found:

First.—That the total length of the screw corresponded nearly with the length of the line standard from which it was cut,

Second.—That there were at many points minute irregularities of pitch, due to the fact that the application of the corrections intermediate between the main divisions had not been exactly made.

Third.—That the crucial test of the removal of these irregularities by grinding with a brass nut was a complete success. As had been predicted, they were for the most part removed after an hour's grinding.

The method of testing was as follows: Two half nuts with projecting arms resting upon the /‾‾‾‾‾‾‾‾\ shaped way were first placed at a fixed interval apart. A microscope was mounted on one nut and coincidence was made between the micrometer wire of the microscope and a line drawn upon the upper surface of the other nut. It is obvious that if the relation between the different threads of the screw remained constant, the line under the microscope would remain constant. This constancy under half-inch objective was maintained for about 20 inches. Then the nuts began to separate, and the separation continued until the maximum deviation amounted to about $\frac{1}{5000}$ of an inch; but near the end the nuts came back to their first relation.

In order to eliminate these residual errors, together with what errors might remain which were a function of one revolution of the screw, the following method was employed. The grinding nut was made in halves, in such a manner that a constant relation was maintained between the halves, both in their normal and in reversed positions. By grinding the screw, first with halves of the nut in their normal relation and then in reversed relations, the tendency was to continually work out the periodic errors of the screw, with the exception of minute errors which were transferred from the screw to the nut during the operation of grinding.

In order that the nut might grind without disturbing the general relation between the threads, a cast-iron cylinder with a center at the bottom was filled with the best sperm oil, and the screw was mounted vertically upon this center. At first two broad fans were attached to the nut in the hope that the resistance of the oil, which in this case would be symmetrical with respect to the axis of the screw, would be sufficient to drive the nut upon the screw. As this movement was found to be too slow, a guiding rod was used.

The grinding process was continued for three weeks, and the results obtained confirmed previous experience. At the end of the first week the maximum error of $\frac{1}{5000}$ of an inch had been reduced about one half, but it was found that small errors had been introduced in the mean time at other points, through a slight transfer of the errors of the screw to the nut itself and from thence back to the screw. Near the end of the second week the screw was clearly less perfect as a whole than at the commencement of the operation of grinding. Mr. Ballou then recut the nut, making its diameter a little less than that of the screw. Within a few hours thereafter a decided improvement was observed. A new nut was made at the end of the second week having its diameter still a little less than before. During the third week the gain consisted for the most part in eliminating the errors which had been introduced during the second week. Throughout the entire operation of grinding, reversals were made every hour both of the halves of the nut and of the screw upon its centers.

Prof. Sweet, in the course of discussion, said that having obtained a practically perfect screw, there remained the difficulty of using it so that it should remain perfect. In using a comparatively short nut on a long screw, the screw under the ordinary conditions of use was unequally worn at different places in its length, the result being that the originally accurate screw soon became full of inaccuracies. Were it possible to use a nut of a length equal to that of the screw the accuracy of the latter might be maintained. Imag-

ine a long and nearly accurate straight edge, but with small local inaccuracies along its length, and then trying to remove these inaccuracies by grinding with a short and perfectly accurate straight edge, and you have a fair idea of the conditions existing in the use of a short nut and a long screw. The accurate straight edge must be as long as the one it is used to correct. He had often thought that, in the lead screw of a lathe for instance, by removing some of the threads on the parts of the screw that were used the least the tendency would be to a better preservation of the accuracy of the screw, but as in many other things, he had never had the courage of his convictions in a sufficient degree to do what he thought was right.

ENGINEERING NOTES.

THE report of the directors of the Panama Canal Company on the present condition of the works states that the number of men employed in May, 1884, was over 19,000. It is calculated that the excavations amount to 110,000,000 cubic meters, in addition to 10,000,000 cubic meters of earthworks in altering the course of the Chagres. Up to the end of April, 1884, the total amount of work done is represented by 5,243,302 cubic meters of earth removed. Until January 1st, 1884, however, the real work of cutting the canal had scarcely fairly begun, and of the total of 5,243,302 cubic meters of earth removed, nearly half, that is to say, 2,482,768 cubic meters have been removed in the first four months of the present year. In the total of 120,000,000 cubic meters of ground to be excavated, 40,000,000 will be taken away by means of dredgers. The projector says there can be no doubt of the canal being open for navigation before the close of 1888.

THE proposal to construct a ship canal across Ireland is again to the fore. The Dublin *Freeman's Journal* has published particulars of the project for constructing a ship canal across Ireland, which it assures its readers is a reality, and has been warmly espoused by influential people in England. "Elaborate plans and surveys have been made at considerable expense, and have been submitted by Captain Eads, the American engineer. The proposed canal would be 127 miles in length, and would contain thirty locks. For ships of 1,500 tons the cost would be £8,000,000; for ships of 2,500 tons £12,000,000; and for ships of 5,000 tons and upwards £20,000,000. If built on this scale the canal would be 200ft. wide on the surface and 100ft. at the bottom. The passage through the canal would be effected by a system of towage, and it is estimated that the passage of a ship from Galway Bay to Kingstown would occupy between twenty-four and thirty-six hours. An alternative scheme of a ship railway, on which the ships would be carried in cradles, which could be constructed for £10,000,000, is proposed, by which the duration of the passage through the island would be reduced to twelve hours An immense aqueduct would have to be constructed to carry the canal over the Shannon at Banogue. It would be over three miles in length, and would be one of the most difficult and costly works in connection with the undertaking."

THE producers of petroleum on the western shore of the Caspian Sea have been contemplating seriously the laying a pipe line entirely across Persia to the Persian Gulf. If this were done they say that they would have the Asiatic market to themselves; which is not so certain, however, because there would be no traffic to the Persian Gulf port for vessels taking petroleum to India, China, &c., from it. A pipe line would have to be something more than 700 miles long to reach the coast, and as it would for a long distance pass through a territory of savage Kurds and other nomadic tribes, it is feared that it could not easily be kept in operation.

THE preparatory measures for the junction of the sea of Aral with the Caspian Sea have reached a further stage by the return to St. Petersburg of the Russian expedition which has been surveying the route. The Russian Government was so convinced of the important nature of the proposed water-way that General Gluchowsky, the originator of the idea, was sent at a cost of nearly £100,000 with a corps of experts and engineers to make the necessary investigations. The results of this step have not been made public, on the ground of their being under examination by a commission. It is, however, concluded in some quarters that the silence of the official press indicates the non-fulfillment of the original expectations.

BRIDGES and structional ironwork have been in fair demand during the past six months, and Messrs. Matheson and Grant in their "Engineering Trades' Report" say: "Prices have fallen only in proportion to the slightly lower cost of iron. The ironwork required at home has been mainly for the widening of railways and the extension of existing stations. The application of machinery to the manufacture of iron structures has been much improved during the last few years; portable as well as fixed hydraulic riveters are now almost universally used, and multiple drills form a more important part of factory equipment than formerly. The English system of riveted connections is still preferred to the American plan of links or 'eye bars' with pin connections, and though bridges according to the latter method come into competition with English bridges in South America, and have even been imported into the Australian Colonies, the English riveted bridges are preferred where stability and permanence are valued. Steel is becoming more used as its price approaches that of iron. Besides the Forth Bridge, which will require about 10,000 tons of steel per annum for the next four years, steel bridges over the Hooghley and the Indus are being made for the In-

dian railways, and will do much to render engineers and manufacturers acquainted with its use. In London, the railway bridge over the Thames at Blackfriars is being doubled, the South-Eastern Railway bridge at Charing-cross is to be widened, Hammersmith Suspension Bridge is to be strengthened, and a new iron bridge is to be built at Battersea. The long proposed bridge across the Thames by the Tower will probably soon be built."

IRON AND STEEL NOTES.

BESSEMER STEEL FOR ENGINEERS' TOOLS.—How nearly Bessemer steel can be brought to crucible in its usefulness for tools is a matter than which there are few more important to the machinery engineer. The advance of the Bessemer metal in this respect means to him a considerable saving of money. It may not, perhaps, be generally known that the Barrow Hematite Steel Company is doing a good deal in the production of Bessemer steel for uses hitherto served by crucible steel. In addition to its usual out-turn of heavy steel, in the form of rails, blooms, tires, &c., the company is producing upwards of 1,000 tons per week of special steel, which is being worked up in various parts of the kingdom into all the following forms:—Roll-turning and lathe-turning tools, chisels, files, shear blades, rail drills, rail punches, shear steel for welding to iron, miners' drills and tools, picks, shovels, hand hammers, roller bar and cotton spindles, locomotive engine, wagon, carriage, coach, and furniture springs, bolts, nuts, rivets, pit-ropes, telegraph, crinoline, and corset wire, umbrella frames, wire for musical instruments, and the like. Nor has cutlery itself been found too hard a test; for this special steel has been made even into razors with decidedly good results. Touching the extent to which the articles answer, it may be mentioned that a 1-inch pit chain, made from a soft sample of this special Bessemer make, withstood a breaking load of 35.63 tons; elongation, 6 inches or 18 inches. The welding had been done by a smith not accustomed to chain work. This is very encouraging to machinery engineers, with whom Bessemer steels are gaining favor to the supplanting of cheap cast steels.

OBSERVATIONS ON HARDENING.—Too many of the so-called steel articles sold in the market are either made from steel incapable of being hardened, or are not hardened at all. Good cast steel can be hardened and tempered so as to receive and retain an edge. This is not required of table cutlery generally—only of the carving knife—but it is required of the hand saw and the buck saw, of the spade and the manure fork, of the scissors and the pocket knife. Saw blades (so far as the writer has tried them) are not hardened; they will not retain "set" nor hold edge. They are gummed as they come from the rolls and the slitting machine, with no pretence at hardening or tempering. But they are stamped "cast steel," and that probably satisfies the public; but there are mechanics who would pay something extra to get good hardened and tempered saw blades, even at a much higher cost than that of the soft plates, the teeth of which can be bent by thumb and finger, and the set of which is removed by sawing through an inch thick spruce board. A spade is only an enlarged chisel; it should be capable of retaining an edge sufficient to cut through tough turf and dead grass. But most of the "cast steel" spades in the market can be sharpened as readily by drawing the edge cold under the hammer as by the grindstone. The edge never breaks, but batters and bends. The trouble with almost all the cast steel tools put ready made on the market is that they have never been hardened. Cast steel unhardened is as soft as wrought iron uncasehardened. A cast steel hammer became so indented on its face by driving nails during one season in jobbing that it had to be reground and polished. Yet the hammer was of steel capable of being hardened, as was proved by its being subsequently hardened and drawn to temper. It is quite possible that the reason why many of these articles prove to be soft is, not that the material is not good, but that they have never been hardened. Brightened steel that has not received a hardening may respond in after-heating to several of the tempering colors; and this is probably one reason why common steel articles are not thoroughly hardened. It is not uncommon to see a forger or temperer heat a piece of cast steel to a very low red—a red that shows only in the shadow—and then brighten and draw the temper to color, when after-trial proved that the steel had never been hardened. Indeed, the dull red that some smiths use for hardening such tools as cold chisels and other low-grade tools is that at which a red annealing may take place, the piece being heated to a dull red and plunged into water. The first requisite in making a cast steel tool into a working tool is to harden it. After its hardness is proved then it may be tempered to the condition required. There is no intermediate process of properly tempering between absolute hardening and subsequent drawing.

RAILWAY NOTES.

THE whole extent—75 miles—of the Coude d'Eu Railway, in the Province of Parahyba, Brazil, constructed by Messrs. Wilson, Sons & Co., was successfully opened for traffic on 4th inst., this being before contract time.

IT is now some twelve years ago that Messrs. Merryweather & Sons, of London, constructed their first steam tramway engine for the late Mr. Grantham. Since the failures of that time the economy and practical value of steam on tramways have been gradually proved in several parts of the world. The measure of success now obtained may be gathered from the fact that Messrs. Merryweather have received an order for fifteen of their tramway locomotives for use on the North London tramways. This tramway company has waited until experience has improved tramway engines sufficiently to add economy to the advantage they offer as to haulage power.

ABOUT 94 per cent. of the double mileage of the railways in England and Wales is now worked on the absolute block system, and the greater portion of the single lines is under the same control, in addition to the train-staff system. In Scotland, the double mileage worked by the absolute block is 90 per cent. of the whole, and in Ireland, 22 per cent.

THE active interest taken by the Austrian Government in the construction of railways in Bosnia and the Herzegovina is being further illustrated by the proposal for a line from Metkovic to Mos ar, following the right bank of the Narenta, and designed to facilitate commerce while also serving useful strategical purposes. Metkovic is at present a point of junction between the steamboat service on the Narenta and the land transports. After the regulation of the stream it is expected that large vessels can reach this point. There are important coal deposits at Mostar. The total length of the line is 26½ miles, and the difference in altitude between the terminal points about 200 feet. The gauge is fixed at 29.92 inches so as to correspond with the Brood-Serajero line. The permanent way will consist of steel rails 3.54 inches in height, and weighing about 34 lbs. per running yard, the maximum gradient not exceeding 1 in 300. There is a tunnel about 150 yards long, and various cuttings through rocky ground, &c. The three stations are principally intended for supplying water to the engines, as the country is thinly populated. The line is estimated to cost £170,000. It is in view to prolong the line to Serajevo, and a branch from Metkovic to Ragusa is also spoken of by the *Deutsche Bauzeitung*.

SOME idea may be formed of the traffic on English railways from the following facts:—Through Farringdon Street Junction of the Metropolitan Railway 1,800 trains pass in twenty-three hours every day. There are four lines of rails, used by the Metropolitan, Great Northern, Midland, London, Chatham, and Dover, and Metropolitan Extension Companies. Through Watford Junction, on the London and North-Western Railway, 233 trains pass every day. This gives something like one in every four minutes of the twenty-four hours. At Cannon Street station, on the South-Eastern line, the number of trains using the station is 750 in one day. Through Clapham Junction the London and South-Western Railway had, in the year 1877, on an ordinary week-day, 656 trains, while on the Derby Day of 1876 no less than 1,023 trains passed through this junction. The number is now over 1,000. The total number of passengers conveyed in 1883, exclusive of season-ticket holders, was—first-class, 36,387,177; second-class, 66,096,784; third-class, 581,233,476; total, 683,718,137; and season-ticket-holders, 180,000,000; total 863,718,137. Of minerals there were conveyed 189,485,612 tons; of general merchandise, 76,897,356 tons; number of miles run by passenger trains, 139,545,464; number of miles run by goods and mineral trains, 129,351,774; total miles run, 268,897,236; miles of railways, 18,668; number of persons employed, 367,660.

THE American Consul, Mr. Lyell T. Adams, at Geneva, writing on the subject of international railway communication, states that any account of the commercial position of Switzerland at present would be incomplete without some reference to the great change impending on the completion of the new lines of international communication, whose effect will be to make her a commercial, as she already is the geographical and hydrographical, center of the Continent. Nothing has isolated her, hitherto, but the altitude above the sea level, now overcome by the Brenner Railway, and the tunnels of the Mont Cenis, the St. Gothard, and the Arlberg recently opened. By these routes the extremities of Europe are brought into direct relations, the meeting point of all lying upon Swiss territory, with the exception of the Mont Cenis. This line crosses Upper Savoy, which, by the treaty of 1815 forms part of the Swiss neutral territory, to be occupied in war by the armies of the Confederation. One of its main feeders is the West Swiss Railway, from Berne to Geneva, and much of its traffic is likely to be diverted by the projected tunnel under the Simplon. What effect, adds Mr. Adams, this reconstruction of the European railway system will have on the fortunes of Switzerland, it is as yet too early to conjecture.

THE construction of the Corinth Canal seems to have tended to increased activity in railway construction in Greece. A railway is being constructed in the Peleponnesus, starting from the Pyræus, which is the port of Athens. The station at Athens is about 1,500 feet in length and 130 feet in width, being near the Academy of Plato. The Kepissos is crossed by a bridge 90 feet in length, and the railway then traverses the north-western plain of Athens to Kameteron, following in a northerly direction the base of the Parnes mountain, subsequently penetrating through the narrow pass of Phylæ, and proceeding through the villages of Charia to Eleusis. The further portion of the railway from Eleusis to Megara was expected to be opened about the present time. The portion of the line from Megara to the Isthmus of Corinth presents the difficulty of a track overhanging the sea at a height of about 190 feet for a distance of nearly six miles, this romantic locality being known as the Scirronic Rocks. The completion of this portion of the line will hardly be possible before a late period of the Autumn. At Corinth the line divides the southern portion terminating at the cities of Argos and Nauplia. The western line follows the coast of the Gulf of Corinth, and goes through Ægium—Vostizza—to Patras. From that point it extends along the west coast of the Peloponnesus through Achaia, Gastuni, and Kalakolon to Pyrgos, in the vicinity of Olympia. The whole district traversed by the railway is thickly populated and in a good state of cultivation, the gain to local commerce being enhanced by the fact that there are scarcely any practicable harbors at that part of the coast.

THE LARTIGUE BALANCE RAILWAY.—A correspondent writes to the *Times:* Already a railway exists in Africa, working several miles, for the conveyance of the alfa plant

paper, which may possibly prove of good service in Egypt. This is the elevated single-rail system invented by M. Lartigue. It is said to be much cheaper in material, in working, and in the rapidity with which it is constructed than any other system. Although, as an agricultural railway, specimens had been exhibited and had gained medals at the exhibitions of Amiens and Amsterdam last year, the railway was first shown with electricity as the motor at the Palais de l'Industrie this spring. At the time I gave particular attention to the subject from an agricultural point of view, and obtained from the inventor himself much information concerning it. In due time it was seen in working order in the exhibition, and became quite a center of attraction, being visited by the president and many of the official notabilities. Messrs. Siemens had supplied, at eight days' notice, a very effective electrical motor, which, attached to light cars running on grooved wheels over a single bar of iron suspended about three feet from the ground, drew along goods and passengers in a very satisfactory manner. So light was it that an American general with me, who had put 250,000 men in the field, pulled along with his simple strength about fifteen cars, with the observation, "These trucks are a going concern." The sections of the rail are wonderfully light, the rail, bar, and standards weighing only about 65 lbs., and the cars for goods 75 lbs. A couple of workmen can set up several hundred yards of the line in a single day. Curves are made by simply bending the rail bar, and a few plain contrivances are applied which meet all the ordinary railway transit exigencies that occur. It is reckoned that the haulage power necessary to move the load on this system is 30 per cent. less than is required upon ordinary double rails. Riders of bicycles will readily understand this. The rail is, in fact, regarded as the backbone of an animal, and the burden is balanced or distributed on either side, hanging baskets or frameworks carrying variously shaped vessels forming cars which run on the center wheels. The center of gravity, being below the point of suspension, is not readily disturbed, so that the difference of half a hundredweight on either side only gives a slight "list" to the load without increasing the friction. Trusses of straw, baskets full of produce, vessels for oil, wine, &c., and frameworks for minerals were shown in various cars, and a passenger car to carry four or six persons was exhibited. This display was at the end of February. On returning to London with many detailed plans and illustrations of the system, I made a point of showing them in various quarters, among others, to the chief engineer at the General Post Office, and to scientific and agricultural friends, some of whom referred to the principle of the saddle-back or balance railway as being old. However, the detailed designs, iron standards, and models of carriages were recognized as novel and practical, while the electrical locomotive was undoubtedly new. Patents, in fact, have been obtained in France, England, America, and other countries. Such being the position, I was not astonished on revisiting France last week to find Lartigue's railway. with its single bar, occupying space at most of the Concours Regionaux. I saw it at Orleans this week attracting notice; and at the Rouen Exhibition, just about to commence, carriages for passengers on a large scale will be shown such as I have this afternoon examined at the foundry at Grenelle. The system is under the consideration of the French Government as one especially suitable for military purposes, forming a flying force from its portability. Along the iron standard, 3 feet or 4½ feet high, runs an iron bar, in which is enclosed and protected a telegraphic wire. Probably soon our own Government will duly consider this new system for military purposes, telegraphic and parcel communication. Our first Commissioner of Works, Mr. Shaw-Lefevre, has already evinced an interest in this French invention, and certainly it is time the system should receive scientific notice on our side of the Channel, which it cannot fail to do if you can afford notice of it in the *Times*. For warehouses, farms, contractors' works, mines, &c., the cost of this system is put at about 4s. 6d. a yard, and carriages of various forms are offered at from 24s. to 48s. each. The estimate given to a mining company in Ireland which has made enquiries for the construction of over two miles of line, to carry 200 tons in ten hours, is, inclusive of thirty carriages, only £1,350—a cost much below that of the miniature railway, running on two rails. The electric locomotive machine of Messrs. Siemens is divided into two parts, disposed and balanced on either side of the rail, following thus the general principle of the system. The motor is a dynamo-electric machine, with the current continued in circuit in connection with a fixed generating machine, and is so contrived that the oscillations of transit do not break the contact. The algebraic formulas and technical descriptions, in which engineers revel when forming comparisons of one system with another, may here be omitted, with the remark that, as French experts have worked out their sum, the results in favor of a railway running on a single bar are such as to commend it to the English public for practical consideration.

ORDNANCE AND NAVAL.

THE SEA-CELL AS A POSSIBLE SOURCE OF DANGER IN TORPEDO-EXPERIMENTS. By H. MOORS.

In considering the cause of a fatal accident, due to the explosion of a torpedo in an experiment conducted on board H.M.S. "Cerberus," the author was led to the conclusion that though in this case it was "not proven," still the electrical action set up between the zinc plate of the torpedo case serving as earth for the firing-current, acting as one pole of a battery when immersed in the sea, and the iron hull of a ship with which the firing-line could accidentally make contact, acting as the other pole, might in certain cases be sufficient to ignite the fuse. A battery thus formed would have no resistance and an electromotive force of about 0.514 to 0.564 volt; the platinum fuse ordinarily adopted has, according to the table given in the "Chatham Instructions in Military Engineering," a resistance of 0.325 ohm cold,

and 0.74 ohm at the fusing-point, the current sufficient to fire a charge being 0.75 ampere; a more sensitive detonator has a resistance of about three times the former, and requires only 0.32 ampere; the conducting wire used in the experiment was such as to give 126.8 yards to one ohm. From these data it results that the total resistance in circuit for firing the ordinary fuse with such a sea-cell would be 0.752 ohm, and allowing for the increase of the fuse's resistance with temperature, it would certainly explode with 44½ yards of such a conductor in its circuit; and, owing to the uncertainty of the data adopted, a far greater margin of safety would be required. Experiments to test this theory were carried out by Messrs. G. S. Caldwell and G. Smibert, of the Post and Telegraph Department (the former was the first to propose the above theoretical deduction as the cause of the accident), and though unpublished, their results were placed at the author's disposal. The experiments were made on board H.M.S. "Malwa;" a zinc plate, 7×3 feet, was lowered clear of the hull, and a small portion of the rail well cleaned, with which the conductor was put in contact, by this means eight fuses of the regulation pattern were exploded through lengths of wire varying from 10 to 41 yards (175 yards of this conductor had a resistance of 1 ohm). An exposed surface of copper in connection with the iron, as was supposed to be the case on the "Malwa," would give a higher electromotive force than iron alone. The conclusions point convincingly to the possibility of accidental ignition from such a cause, and the necessity for due precautionary measures to prevent any such accidental contact in all torpedo experiments.—*Abstracts of Association of Civil Engineers.*

BOOK NOTICES

PUBLICATIONS RECEIVED.

From Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers:

Emery Wheels and Emery Wheel Machinery. By Walter Osmond Rooper.

The Storage and Shipment of Grain. By Woodford Pilkington, M. Inst. C.E.

Experiments on Transmission of Heat. By Gustav Adolph Hageman.

The Basic Open-Hearth Steel Process. By Thomas Gillott, M. Inst. C.E.

The New York, West Shore and Buffalo Railway. By Peter Chalmers Cowan.

The Comparative Value of Labor in Different Countries. By Charles Ormsby Burge, M. Inst. C.E.

STADIA SURVEYING. By ARTHUR WINSLOW. Van Nostrand's Science Series, No. 77. New York: D. Van Nostrand. Price 50 cents.

Since good authorities have determined that with proper instruments the stadia method of measuring distances is as reliable as average chaining there has been manifested a strong disposition to adopt the method in quarters where it was heretofore unknown.

The inquiry for a suitable guide to the method had become quite a brisk demand before Mr. Winslow's essay was printed in the pages of VAN NOSTRAND'S MAGAZINE.

The formulas and tables are such as are employed on the Geological Survey of Pennsylvania, and they form a part of the official report.

It is rare that so complete a treatise on the theory and practice of a method in surveying is found in so small a volume.

Besides the stadia tables the book is furnished with a table of logarithmic sines and tangents to four places of decimals.

RECHERCHES SUR L'ELECTRICITE. Par GASTON PLANTE. Paris: Revue la Lumiere Electrique. Price $3.50.

The importance which secondary batteries and accumulators have of late assumed has invested with a new interest the labors of M. Planté.

The treatise before us is divided into six parts. The first treats of accumulation and transformation of electric energy by aid of secondary currents. The second part treats of applications. The third part contains "Effects of Currents of High Tension." The fourth part, "Analogies between the Effects of High Tension and some Natural Phenomena." In the fifth part is described the Rheostatic Machine. The sixth part discusses the analogies between electric phenomena and some purely mechanical effects.

The book is beautifully printed and illustrated.

A TREATISE ON EARTHY AND OTHER MINERALS AND MINING. By D. C. DAVIES, F. G. S. London: Crosby, Lockwood & Co. Price $5.00.

This book is devoted to an account of the more important minerals, their properties, localities and mining. The so-called useful and the precious or noble metals—in short, all those which are commonly used in the metallic state—have been discussed by the author in a previous treatise on "Metalliferous Minerals and Mining."

The minerals to which considerable space is given are, first, silica, and the chief combinations of alumina, magnesia and lime. Then in order come salt, sodium nitrate, borax, baryta and gypsum. Phosphate of lime is discussed through four chapters. Three chapters are given to carbon and one to sulphur.

What the author calls metallic minerals are represented by arsenic, cobalt, molybdeseum, antimony and manganese.

The illustrations are numerous, but rather poor, and as the above schedule indicates, the work is manifestly incomplete.

FORESTS AND FORESTRY OF NORTHERN RUSSIA. By JOHN CROUMBIE BROWN, LL. D. London: Simpkin, Marshall & Co.

In this, Dr. Brown has contributed another addition to his long list of treatises on Forestry. In this essay, as in the one immediately preceding it, there is to be found a large fund of information regarding the physical geography of the area described.

Part I. is devoted to a general description of

the forest lands, embracing besides the northern portion of Russia proper, Lapland, Nova Zembla, and regions still beyond.

Part II. deals with Forest Exploitation, and relates to all the Forest Industries, including the manufacture of tar, turpentine and vinegar.

Part III. gives briefly an account of the Topography, Fauna, Flora and climate of the region —in short is a concise treatise on Physical Geography of Northern Russia.

MEMORIAL OF ALEXANDER LYMAN HOLLEY, C. E., LL. D. New York: American Institute of Mining Engineers.

The reader will find in this memorial a skillfully-arranged summary of the literary and practical works of Mr. Holley. The book is pleasant reading, not alone from the fact that much of it is the composition of a near friend who wields a graceful pen, but also from the fact that the most earnest praise in the volume is from the foremost men in Mr. Holley's profession; men who were the best possible judges of his worth and his work, and who regard with evident pride the record of their compatriot.

At the memorial session of the American Institute of Mining Engineers, held a few weeks after Mr. Holley's death, the following summary of the qualities of their deceased member was expressed by Hon. Abram S. Hewitt: "I think that even now, so soon after his departure, we can assign him to the place which he will hereafter occupy in the history of mechanical industry—a mechanical engineer of unerring judgment, an inventor of the true means for great results, a lover of his race, who subjected his science, his talents and his labor to the good of his fellowmen; and he will live in the memory of those who knew him, and in the grateful recollection of those who will come after him, for many a generation."

A list of Mr. Holley's literary works forms the seventh chapter of the memorial. The earliest mentioned paper bears the date 1850, three years before Holley graduated at Brown University. Many short articles are only referred to collectively in a foot note, but enough is clearly specified to prove that Mr. Holley was one of the most industrious of scientific men. He was the first editor of this Magazine, relinquishing it at the end of the first year on account of the pressure of his practical work.

HOUSE DRAINING AND SANITARY PLUMBING. By WM. PAUL GERHEID. New York: D. Van Nostrand. 2d edition, revised 1884. Van Nostrand's Science Series, No. 63. Price 50 cents.

The author is chief engineer of a company actively engaged in pushing improvements in this special line. The position is eminently adapted to produce a valuable book, if not too partisan. We do not observe the latter fault. On the contrary it appears remarkably fair in its enumeration and courses of the various devices in use in all the divisions of the subject from "Wash Basins" to "Trap on basin Drain."

He has managed to say a good deal on this vitally important subject in a 12mo book of 240 pages. The illustrations are peculiarly aggregated on larger sheets than the pages, and folded in. The inconvenience is more than balanced by the facility it affords for comparison. There is danger that with much use such illustrations will be detached, or at least mutilated. But it is a consoling reflection that the end is progressing with such strides that few will care to study these sections, except as curiosities, ten years hence.

The importance of being able to determine at moderate expense, in all situations, whether there are any considerable openings in the drainage pipes in a house can hardly be over estimated. The test of filling the interiors with a strong and marked odor has been long practiced by plumbers, and can be applied by any householder. It is described on pages 62 and 63.

An enumeration of five separate points on page 68 serves as a text for much of the succeeding portions. The book details, down to the latest steps of progress, how to attain these several points.

We pronounce this work, as now revised, the most practically important of this entire fifty-cent series. It is the most likely to do good by its extensive circulation. The community owes a debt to the author and publisher for disseminating this kind of information.

THE PRINCIPLES OF VENTILATION AND HEATING, AND THEIR PRACTICAL APPLICATION. By JOHN S. BILLINGS, M. D., LL. D. (Edinb.), Surgeon U S. Army. The Sanitary Engineer, N. Y. 1884. Price $3.00.

Ever since the tailless animal reached the stage of refinement at which he commenced to avail himself of a covering of leaves, grass, turf, logs or snow, to defend himself against the heat, wet or cold, the question of how to live at the bottom of an ocean of air and have enough of it to breathe, has been before him.

Ever since Prometheus brought fire from heaven, or mankind some other way invented artificial warming, he has been confronted with the further difficulty—how to make fire available to ventilate; or, in many cases, has been obliged to "give it up," on the simpler problem—how to ventilate sufficiently in winter without too much cooling his building. This book is a valuable contribution towards its solution. But it shows that it is not yet solved.

Some forty years ago a wealthy gentleman of this city constructed a stable with an air passage from each stall out through the roof. His horses had celds all the time, till he closed them.

The Klamath Indian along the line between California and Oregon, in composing himself and his heterogeneous family for sleep in cold weather, lets the fire go entirely out, and then tightly closes the only orifice in his small earth hut. Exact scientific calculation, writes a friend of ours who was at one time surgeon at Fort Klamath, shows that they will all be dead at ten minutes before three. They perversely live and flourish.

This book is eminently a collection of facts, but these two facts are not in the volume. The chief fault one finds in reading it, with a desire to learn the latest, or rather the best plans, is the

absence of a clear statement of what the author recommends. He says, in substance, the amount of ventilation practicable with efficient warming depends on the expense which the owner is willing to incur in the construction, and in the subsequent fuel bills, a truism which no one can gravely dispute; but when we ask how to spend money, with tolerable assurance that the ventilation will be right so far as it goes without interfering with the warming, if the answer is there, it is not as conspicuous as we would like to see it. The United States Government expended liberally in ventilating the magnificent room—the House of Representatives in Washington.

Possibly some may consider the book better for omission of any recommendation. We do not. When one is familiar with the subject we deem it not quackery, but the opposite, the conclusion of one who has given much well-trained thought, observation and experience to his subject. To tell us how, it is due to the public. The preface tells us the object of the writer is "to present the general principles which should guide one in judging of the merits of various systems of, and appliances for, ventilation, more especially as applied to large public buildings." Engravings and descriptions are given of the provisions for warming and ventilating many buildings.

The elaborate description of steam-heating pipes, fans, distributing passages, and exhausting shafts in Mr. C. N. Dickenson's house, the Fifth Avenue Presbyterian Church (Dr. Hall's), Metropolitan Opera House, Madison Square Theatre, Union League Club, and Columbia College, New York; the south wing United States Capitol, and Barnes Hospital at Old Soldiers' Home, Washington; the House of Lords and House of Commons, London; Grand Opera House, Vienna; St. Petersburg City Hospital, Russia, and other buildings of less note, with his evidently fair statement of the remaining difficulties in most or all the cases, leave one with a painful sense of the little, instead of the much, which is known about ventilation. At Dr. Hall's church, he writes (p. 111); of Mr. Dickenson's house, our author writes (p. 69); of the latest and best result in the U. S. Capitol.

Our author gives with faint approval the leading features of the Ruttan system, a system devised by a wealthy Canadian, the late Henry Ruttan, who lost some members of his family by lung diseases, and spent the rest of his lifetime in devising and carrying out a plan of natural ventilation, excellent for dwellings and all buildings not crowded. We esteem the Ruttan system. Pouring the air in at the top and taking it out at the bottom deserving much more attention.

This book is valuable, immensely valuable. Its work is in a line beyond mere dollars and cents. Dr. Billings as author, and the Sanitary Engineer proprietors as publishers, are doing missionary work, in spreading light on this subject. If the light is foggy, it goes to show if any proof were needed that this subject is one which needs this book, and much still further skillful observation, experiment and successful practice with a still further wide-spread publication of the result.

MISCELLANEOUS.

In a lecture on the fixed stars, Dr. David Gill, F. R. S., said: "Light takes almost exactly 500 seconds of time to come from the sun; this is a figure easy to remember, and is probably exact to a single unit. The sun is ninety-three millions of miles distant, and this figure I believe to be exact within 200,000 miles. Quite recently the accuracy of these figures has been confirmed in a very remarkable way by different kinds of investigations by different observers, otherwise I should not have quoted them with so much confidence. The parallax of α Centauri is three-quarters of a second of arc; therefore its distance is 275,000 times the distance of the earth from the sun, and therefore light which travels to the earth from the sun in 500 seconds—*i. e.*, in 8⅓ minutes—would take 4.36, or a little more than 4½ years to come from α Centauri."

Rubennick's process for metalizing wood consists in steeping the wood in a caustic alkali for two or three days, according to its degree of permeability, at a temperature between 164 deg. and 197 deg. Fah. The wood is then placed in a second bath of hydrosulphate of calcium, to which is added, after twenty-four or thirty-eight hours, a concentrated solution of sulphur. After forty-eight hours the wood is immersed in a third bath of acetate of lead at a temperature between 95 deg. and 122 deg. Fah., where it remains from thirty to fifty hours. After a complete drying the wood thus treated is susceptible of a very fine polish, especially if its surface is rubbed with a piece of lead, tin or zinc, and finally finished with a burnisher of glass or porcelain. It then looks like a metallic mirror, and is completely sheltered from all the deteriorating effects of moisture.

Reports from the National Armory at Springfield, Mass., speak well of the new ramrod bayonet. The bayonet portion of the ramrod is 15 inches long, slightly thicker than an ordinary rod, with a four-grooved blunt point. It is held in position when ready for use by a simple spring clasp, invented by Col. Buffington, and when not wanted is pushed down until it occupies the same position as the ordinary Springfield rifle ramrod. On the experimental gun which has recently been fitted up according to Colonel Buffington's plans, a guarded bead front sight is used, and also a 2,000-yard screw adjustment peep hind sight, with a 1.4 inch windage movement. An automatic allowance for the bullet "drift" is one of the features of the new pattern hind sight.

A paper on "The Formation of Sugar in the Sugar-cane," was recently read by M. Aime Girard before the Paris Academy of Sciences. By comparative investigations of the amount of cane sugar and grape sugar in different parts of the sugar-cane in the afternoon and before sunrise, the author has found that only in the substance of the leaves does this quantity vary, and that the quantity of cane sugar sinks during the night to one-half, whilst the quantity of reducing sugar remains almost unaltered. He finds further that the quantity

of cane sugar in the leaves increases with the illumination, on very bright days reaching nearly one per cent., considerably less on dull ones, and in either case diminishing during the night by one-half. From this the author concludes that the formation of saccharose from glucose takes place entirely in the leaves under the influence of sunlight, and that the saccharose thereupon ascends the cane through the petioles, &c., and collects there.

IMPROVEMENTS IN BRONZE AND BRASS ALLOYS.—A patent has been obtained by Prof. A. K. Huntington for improvements in metallic alloys, the object of which is to secure strength, elasticity, and closeness of grain by the addition of a cheap and easily accessible material. For this purpose, to the copper or alloy he adds a small quantity of silicious iron which may contain a small proportion of other metals, such as manganese, tungsten, or the like. The mixture is made while the materials are in a molten state and as nearly as possible at the same temperature. As examples of alloys made according to the invention, to copper and tin in the usual proportion for gun-metal add not more than 2 per cent. silicious iron; to copper and tin in the usual proportion for brass add not more than 5 per cent. silicious iron; in bronzes or brasses where tin is present besides copper and zinc, a less proportion of silicious iron is used than when there is no tin. Generally, when zinc forms part of the alloy it is preferred to use silicious iron containing a proportion of manganese.

M. LAZARE WEILLER has conducted a series of valuable experiments with the object of ascertaining the relative electric conductivity of metals, submitting the results to the Société Internationale des Electriciens. They are referred to a pure silver wire, 1 millimeter in diameter, and having a resistance of 19.37 ohms per kilometer at 0 deg. C., as a standard. The following are his figures:—Pure silver, standard 100.00; pure copper, 100.00, silicon bronze (telegraph), 98.00; alloy of equal parts silver and copper, 86.65; pure gold, 78.00; pure aluminum, 54.20; silicon bronze (telephone), 35.00; pure zinc, 29.90; phosphor bronze (telephone), 29.00; alloy of equal parts silver and gold, 16.10; Swedish iron, 16.00; pure Banca tin, 15.45; 10 per cent. aluminum bronze, 12.60, Siemens steel, 12.00; pure platinum, 10.60; pure lead, 8.88: pure nickel, 7.89; antimony, 3.88.

M. EDOUARD LANDRIN, who had previously shown that when an intimate mixture, in certain proportion, of pure lime and quartz is raised to a white heat, the resulting cement sets slightly on contact with water, but becomes very hard in the presence of carbonic acid, has shown us the results of some new experiments on the hydraulicity of cements that (1) silicates of lime raised to high temperatures set with difficulty, and in any case do not harden in water, according to M. Fremy's experiments; (2) for the calcination of cements to exert a maximum influence on the setting, in connection with water, of the compound obtained, the process must be carried sufficiently far for the lime to act on the silica so as to transform it into hydraulic silica and not into fused silica: and (3) carbonic acid is an indispensable factor in the setting of siliceous cements, inasmuch as it is this substance which ultimately brings about their hardening.

MR. C. V. BOYS recently read a paper before the Physical Society on a phenomenon of electro-magnetic induction. Between the poles of an electro-magnet a small disc of copper is hung by a bifilar suspension. If the magnetic field is uniform and the disc at an angle to the lines of force, then on making the magnet it is jerked parallel with the lines of force. If it is a changing field, and the disc perpendicular to the lines of force, it is repelled on making the magnet and attracted on breaking by the nearest pole. This phenomenon, which was observed by Faraday, was shown by Mr. Boys to be useful for determining the intensity of a magnetic field by measuring the throw of the disc on magnetizing and demagnetizing. It might also be employed to measure the resistance of bodies in the form of plates, from their diameter, moment of inertia, and observed throw. Any structural difference of resistance in different directions in the body might be determinded by its means. Mr. Boys illustrated his remarks with curves of results obtained by experiment. Lord Rayleigh considered that the effect of self-induction on the results was not likely to be serious.

AN important piece of work has just been brought to a successful conclusion in Rome, in the complete renewal of the leaden envelope of the dome of St. Peter's Church, in Rome. It has occupied twelve years, and has cost over 200,000 lire (£8,000). The original covering was applied to the dome in an imperfect fashion, which made continuous repairs a necessity; and at last it was determined to strip off the whole envelope and substitute a new one on a better system. New lead was imported from Spain and mixed with the old lead, in the proportion of one part old to two parts new. The total weight of the new cover is given at 354,305 kilogrammes, and if it were spread out flat it would occupy an area of 6,152 square meters, or about an acre and a half. In stripping off the old plates three of them were found to be of gilded copper.

AT a recent meeting of the Berlin Physical Society, Professor Lampe spoke on the on the subject of a hypothesis respecting the formation of the solar system set up by M. Faye in place of Laplace's hypothesis. According to M. Faye's theory, in the original uniform nebular mass, vortices were formed which gave rise to the existence, first, of the middle planets, and then, ultimately, of the outer planets. This hypothesis was advanced as an explanation of the fact that the moons of Uranus and Neptune revolved in a direction opposite to that of the sun, the planets, and the other moons, a fact which was not accounted for by Laplace's theory. Only a brief communication, however, had yet been published of M. Faye's hypothesis, which, too, appeared to betray a number of lacunæ.